FINE PARTICLE ($PM_{2.5}$) BOUNDARY RECOMMENDATION

And

Technical Support Document for the Determination of Boundaries in Missouri for the $PM_{2.5}$ National Ambient Air Quality Standard

Adoption
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FINE PARTICLE BOUNDARY RECOMMENDATION

Introduction

This purpose of this document is to summarize the analysis of the National Ambient Air Quality Standard for $PM_{2.5}$ in Missouri to support a recommendation to EPA for designation of geographic areas in the state as nonattainment for $PM_{2.5}$. In general, the analysis is based on information collected from the years 2000 – 2002 and the April 1, 2003 U.S. Environmental Protection Agency (EPA) guidance for developing the $PM_{2.5}$ designation recommendations. The Missouri Department of Natural Resources' Air Pollution Control Program developed the "Technical Support Document For Determination of Nonattainment Area Boundaries in Missouri For the $PM_{2.5}$ National Ambient Air Quality Standards" to assemble the information necessary to make the recommendations and to address each EPA criteria in detail.

Summary of Recommendation

This recommendation has been developed based on a review of the technical information as required by EPA guidance. Of primary consideration is a review of the counties that do not meet or that contributes to ambient air quality in a nearby area that does not meet the $PM_{2.5}$ NAAQS.

The only $PM_{2.5}$ monitor in Missouri that currently violates the $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) is located in the City of St. Louis. Therefore, the only area of the state that merits a nonattainment designation for $PM_{2.5}$ is a geographic area surrounding this monitor in St. Louis. The proposed boundary includes the Counties of St. Louis, St. Charles, Franklin, Jefferson and the City of St. Louis. This boundary is identical to the proposed recommendation for the 8-hour ozone nonattainment boundary designation. These counties contain the majority of Missouri $PM_{2.5}$ precursor emissions and include the contiguous urbanized portion of the region.

The remainder of the state of Missouri is recommended for designation as attainment/unclassifiable.

Background

On July 18, 1997, EPA promulgated $PM_{2.5}$ air quality standards (62 Federal Register 38652). These standards were based on a number of health studies showing that increased exposure to $PM_{2.5}$ is correlated with increased mortality and a range of serious health effects, including aggravation of lung disease, asthma attacks, and heart problems. EPA established a new annual $PM_{2.5}$ annual standard of 15 micrograms per cubic meter and a new 24-hour $PM_{2.5}$ standard of 65 micrograms per cubic meter. Under the same action, EPA retained the existing PM_{10} standard.

Fine particles ($PM_{2.5}$) are generally emitted from activities such as industrial and residential combustion and from vehicle exhaust. Fine particles are also formed in the atmosphere when gases such as sulfur dioxide, nitrogen oxides, and volatile organic compounds, also emitted largely by combustion activities, are chemically transformed in the atmosphere into particles.

The new $PM_{2.5}$ NAAQS was challenged in the courts, but after five years (March 2002) the District of Columbia, Circuit Court, ruled in favor of EPA, "finding the challenged air quality standards neither arbitrary nor capricious. . ."

The designation process is the first step of addressing this important public health issue. The Clean Air Act allows each state to recommend initial designations of the attainment status for all areas of the State. Section 107(d)(1) of the Act allows each state the opportunity to recommend attainment/unclassifiable and nonattainment areas including appropriate boundaries. EPA can then accept the recommendations or make modifications, as it deems necessary.

The deadline for submittal of Missouri's recommendation is February 15, 2004. By July 2004, EPA is to notify Missouri concerning any modifications to the recommendation, and allow for comments to those changes. The deadline for EPA to finalize the boundary designation is December 15, 2004.

Upon designation, states have three years to prepare State Implementation Plans (SIPs) to address $PM_{2.5}$. EPA intends to publish an implementation rule very soon, that will establish requirements for $PM_{2.5}$ nonattainment areas. The deadline for attaining the $PM_{2.5}$ standard is no later than five years after the formal submittal of the $PM_{2.5}$ SIP. It is possible that the implementation rule will change these deadlines. EPA is also planning to propose a $PM_{2.5}$ transport rule sometime in 2005, and finalize it during 2006. This rulemaking may also affect deadlines. As it currently stands, states will have to submit their $PM_{2.5}$ SIPs in the 2007-2008 time frame, with the attainment date sometime between 2009 and 2015.

Criteria for Designation

EPA published a guidance document titled "Designation of the Fine Particle National Ambient Air Quality Standards" on April 1, 2003. This guidance was written to outline the information that states are expected to consider when making their nonattainment boundary recommendations. In that guidance, EPA recommends that the Metropolitan Statistical Area (MSA) or Consolidated Metropolitan Statistical Area serve as the presumptive boundary for the $PM_{2.5}$ nonattainment area. The presumptive use of the MSA is based on evidence that violations of the $PM_{2.5}$ standard generally include a significant urban-scale contribution as well as significant regional contributions.

The Missouri portion of the St. Louis MSA is comprised of the current 1-hour ozone nonattainment area (City of St. Louis, and St. Louis, St. Charles, Franklin, and Jefferson Counties) and Warren and Lincoln Counties.

EPA's guidance also suggests that states consider aligning their $PM_{2.5}$ boundary designations with their 8-hour ozone boundary recommendations because there is a significant overlap in assumptions, emission sources, and emission control concerns.

On August 1, 2003, Missouri recommended that the an 8-hour ozone nonattainment boundary be established in the St. Louis area and include the City of St. Louis, and the Counties of St. Louis, St. Charles, Franklin, and Jefferson.

To add or remove geography from the presumptive boundary (the Metropolitan Statistical Area), and to consider alignment with the 8-hour standard, EPA's guidance requires each state to address the following factors:

- Emissions
- Air Quality
- Population Density and Degree of Urbanization including Commercial Development
- Traffic and Commuting Patterns
- Expected Growth
- Meteorological Influences (Weather and Transport Patterns)
- Geography and Topography
- Jurisdictional Boundaries
- Level of Current Emission Controls (Emission Control Potential)

Analysis of these factors may suggest nonattainment boundaries that are either larger or smaller than the MSA.

Several of these factors are of little concern in St. Louis. There are no geographical or topographical features that play much of a role in ambient $PM_{2.5}$ concentrations. Meteorological influences also play a limited role. It has been difficult to identify specific meteorological regimes that create elevated $PM_{2.5}$ episodes. There is little pattern to the seasonality of $PM_{2.5}$ episodes, and if there are any meteorological influences they are not consistent and not well understood. Because the $PM_{2.5}$ standard of concern is an annual basis, all weather patterns contribute to the average concentration. For this reason, geography, topography, and meteorological factors affect all of the considered counties the same. These factors are not discussed in the analysis of individual counties.

Lastly, the 24-hour PM2.5 standard has not been considered in this review. There are no violations of this standard recorded at any of the Missouri monitoring sites.

Process for Developing Recommendations

The department's Air Pollution Control Program developed this document and it was widely shared with stakeholders. An informational meeting with stakeholders was held on December 2, 2004, where the proposed boundary recommendation was presented and discussed. The document was then presented at public hearing on December 2, 2003,

before the Missouri Air Conservation Commission. No public comments were received, therefore no changes have been incorporated.

Boundary Considerations – Technical Discussion

The St. Louis $PM_{2.5}$ nonattainment area will be a bi-state area with several counties from Illinois being included. This evaluation was limited to the Missouri counties. Counties or portions of counties that exhibit a pattern of significant contribution are included in the $PM_{2.5}$ nonattainment area. A review of the contributing factors must be done in a consistent manner. In some cases a review of one of the factors argue for inclusion, but a review of other factors may not. The decision of whether or not a county is included must be made in a holistic fashion. Due to the fact that each county has unique characteristics, each county must be evaluated through comparison to other counties.

Section 107(d)(1)(A) of the Clean Air Act defines a nonattainment area as any area that does not meet or that contributes to nearby areas not meeting the ambient air quality standard. The implementation of specific control strategies is not a part of this analysis. The selection of control strategies falls under the SIP process not the process of establishing nonattainment boundaries.

To determine trends, to make county comparisons, and to evaluate the information in a comprehensive manner, the department's Air Pollution Control Program chose to begin the review with counties that had monitors showing violations of the standard. The next group of counties reviewed was the counties that comprised the 1-hour ozone nonattainment area (the same counties have been recommended for inclusion in the 8-hour nonattainment area). The third group considered was those counties within the MSA. And finally, the counties surrounding the MSA were considered. To summarize the review was done in this phased order: 1.) St. Louis City, 2.) Franklin, Jefferson, St. Charles, and St. Louis Counties, 3.) Lincoln and Warren Counties, and 4.) Crawford, Gasconade, Montgomery, Pike, St. Francois, Ste. Genevieve, and Washington Counties.

- **City of St. Louis**

The first consideration for area designation is based on air quality data to determine if an area violates the $PM_{2.5}$ National Ambient Air Quality Standard. The annual standard is met when the 3-year average of annual arithmetic means is less than 15.05 micrograms per cubic meter, due to rounding. The Blair Street monitor is the only Missouri monitor that is in violation of the NAAQS. The South Broadway site may violate the standard when three full years of monitoring is completed. The Blair Street and Broadway Street monitors are both located within the City of St. Louis. For this reason alone, the City of St. Louis will be included in the nonattainment area.

$PM_{2.5}$ speciation data provides insight. Sulfate tends to be high in the summer and contributes to summer mass peaks and Nitrate tends to be high in the winter and contribute to winter mass peaks. Organic and elemental carbon peaks don't show as much seasonality, but tend to occur more in the fall. A comparison of monitoring data

between urban and rural sites suggests that the rural background $PM_{2.5}$ mass concentration is approximately 11 micrograms per cubic meter ($\mu g/m^3$). Therefore, the urban excess ranges up to 5 micrograms or so. As explained in the Technical Support Document (page 9) the urban excess can be further characterized by species as follows: Sulfate ~ 0.5 $\mu g/m^3$, Ammonium ~ 0.2 $\mu g/m^3$, Nitrate ~ 0.6 $\mu g/m^3$, Total Carbonaceous Mass ~ 2.5-3 $\mu g/m^3$, and Crustal ~ 0.6 $\mu g/m^3$. The data shows that the total carbonaceous mass is the species that contributes most to the urban excess. This conclusion has been confirmed in other studies around the country. It is likely that the carbonaceous mass has more of a local origin, and is less likely to be from transport.

Emissions in the City of St. Louis also argue for inclusion in the nonattainment area. In comparison with the other Missouri counties the City of St. Louis is second in total VOC emissions, second in total NOx emissions, fifth in total SOx emissions, and fifth in total $PM_{2.5}$ emissions. The City of St. Louis also ranks second in mobile emissions for every primary and secondary $PM_{2.5}$ pollutant. (Note: total includes Point, Area, and Mobile sources only)

Traffic and commuting patterns as well as population density and degree of urbanization also clearly argue for inclusion of the City in the nonattainment area. The population of the City of St. Louis is expected to decrease significantly over time, but the area will retain a significant commuter base.

The City of St. Louis is centrally located such that there are significant emissions from upwind counties for many wind regimes. St. Louis City is the closest area to the Illinois monitors that are violating the $PM_{2.5}$ NAAQS. The location of the City in relation to these counties also suggests inclusion of the City in the nonattainment area.

<u>Conclusion</u>: Many factors clearly show that the City of St. Louis should be included in the nonattainment area. The primary consideration is the fact that ambient air monitoring in the City shows violations of the $PM_{2.5}$ NAAQS.

- **St. Louis County**

There are no monitors in St. Louis County that violate the $PM_{2.5}$ NAAQS. Values range from 12.4 to 14.5 $\mu g/m^3$. The question then becomes does St. Louis County contribute to $PM_{2.5}$ violations in the bi-state urban core.

The most significant factor that argues for inclusion of St. Louis County in the nonattainment area is emissions of $PM_{2.5}$ precursors. Approximately 46 percent of the total VOCs emitted in the Missouri MSA are from St. Louis County, ranking this County as the highest VOC emitting county in the Missouri MSA. St. Louis County also ranks first in total NOx emissions, fourth in total SOx emissions, first in total $PM_{2.5}$ emissions, and second in total NH_3 emissions. When evaluating emissions and their impact on ambient $PM_{2.5}$ concentrations, it is important to recognize that the location and type of emissions have a significant influence on their impacts. For example, one ton of emissions from a distant location has much less impact than a ton of emissions from a

more nearby location. Emissions from St. Louis County have a much more significant impact than emissions from more distant counties. A review of the various graphs included in the Technical Support Document (pages 29-35) show that emissions from sources in St. Louis County are very significant, and clearly support inclusion of St. Louis County in the $PM_{2.5}$ nonattainment area.

Speciation monitoring results in St. Louis County agree quite well with the monitors located in the City. The same conclusions can be made. Sulfate tends to be high in the summer, Nitrate tends to be high in winter, and carbon peaks don't show as much seasonality, but tend to occur in the fall. Sulfate is widespread and results with contributions from both nearby and distant sources.

Again, a comparison of monitoring data between urban and rural sites suggests that the rural background $PM_{2.5}$ mass concentration is approximately 11 micrograms per cubic meter ($\mu g/m^3$). Therefore, the urban excess in St. Louis County ranges up to 4 micrograms or so. This monitoring data suggests that local contributions are significant.

The population of St. Louis County greatly exceeds the population of the other counties in the Missouri MSA, comprising 39% of the total population of the Missouri MSA. The population of St. Louis County is expected to gradually increase. These factors also argue for inclusion of St. Louis County in the nonattainment area.

Another factor for consideration is traffic and commuting patterns. St. Louis County leads all other Missouri MSA counties in Vehicle Miles Traveled (VMT). In comparison to other counties, the connectivity of residence to work location is also high. These traffic considerations are also reasons to include St. Louis County in the $PM_{2.5}$ nonattainment area.

Conclusion: Emissions from St. Louis County support inclusion in the $PM_{2.5}$ nonattainment area, as the information shows that they clearly contribute to violations of the $PM_{2.5}$ NAAQS. The population and traffic patterns strongly support this conclusion as well. There are few, if any, factors that do not support inclusion of St. Louis County.

- **St. Charles County**

There are no $PM_{2.5}$ monitors located in St. Charles County, therefore the primary question becomes does St. Charles County contribute to the violations in the bi-state urban core. Speciation data of monitors located within the City of St. Louis do provide insight to help answer this question.

As mentioned previously, Sulfate tends to be high in the summer and contributes to summer mass peaks and Nitrate tends to be high in the winter and contribute to winter mass peaks. Organic and elemental carbon peaks don't show as much seasonality, but tend to occur more in the fall.

A significant factor that argues for inclusion of St. Charles County in the $PM_{2.5}$ nonattainment area is emissions of these precursors. St. Charles is the third ranked county in the Missouri MSA in total VOC emissions, representing approximately 13 percent of the total. St. Charles also has significant NOx emissions, ranking third in this category as well. St. Charles ranks second in total SOx emissions and third in total $PM_{2.5}$ emissions. Only an estimated 948.5 tons per year of NH_3 are emitted in St. Charles County, even below some of the Missouri counties that surround the Missouri MSA.

Because of location, emissions from St. Charles County have a much more significant impact than emissions from Counties that are more distant to the bi-state urban core. A review of the emission graphs in the Technical Support Document (pages 29-35) support inclusion of the St. Charles in the $PM_{2.5}$ nonattainment area.

St. Charles County also has a large population. After St. Louis County and St. Louis City, St. Charles has the next highest population comprising approximately 14 percent of the Missouri MSA. The population of St. Charles has grown at a very high pace, and that is expected to continue with an estimated growth rate of 46 percent by the year 2020. This is very significant because of the increase in expected activities and the associated mobile source emissions. An analysis of the population statistics argues for inclusion of St. Charles County in the $PM_{2.5}$ nonattainment area.

Another factor for consideration is traffic and commuting patterns. St. Charles County has a significant amount of vehicle activity and high daily VMT. There is a great deal of connectivity of St. Charles residents with work locations located in St. Louis County and St. Louis City. This is expected to continue, and strongly suggests inclusion of St. Charles.

While the population of St. Charles is relatively high, portions of the county are certainly not considered urbanized. The population density drops off as the distance increases from the primary highways. Along the major highways, however, the population density is significant.

Conclusion: Emissions, proximity, population statistics, and traffic patterns support inclusion in the $PM_{2.5}$ nonattainment area. The most significant factor is emissions, with population and traffic patterns also strongly supporting the recommendation.

The only factor that does not support inclusion is the rural nature of some areas of St. Charles County. Overall, the data strongly support inclusion of St. Charles.

- **Franklin County**

There are no $PM_{2.5}$ monitors located in Franklin County, therefore the primary question becomes does Franklin County contribute to the violation in St. Louis City. As explained in previous analysis, speciation data of monitors located within the City of St. Louis do provide insight to help answer this question.

As mentioned previously, we must consider both seasonal trends and the speciation of the urban excess. It was previously stated that the greatest species contributing to urban excess is total carbonaceous mass. So the activities in Franklin County that are responsible for carbonaceous mass are a concern, as well as other precursors more traditionally understood as pollutants that are transported.

One of the primary factors that argue for inclusion of Franklin County in the $PM_{2.5}$ nonattainment area is population, traffic, and commuting patterns. There is significant overall VMT in Franklin County, especially compared to other counties that are not being recommended for inclusion. The connectivity of Franklin County to the other counties recommended for inclusion is considerable. 31 percent of Franklin County residents work in St. Louis County or St. Louis City, and 95 percent work in proposed $PM_{2.5}$ nonattainment area. The Franklin County workforce population is much higher than the other surrounding counties that were not included in the $PM_{2.5}$ nonattainment area.

Large portions of Franklin County could be classified as rural, but there are pockets of significant population density and urbanization. The population of Franklin County is estimated 93,807, comprising approximately 5 percent of the total population of the Missouri MSA. The population of Franklin County is expected to grow quite rapidly at an expected rate of approximately 25 percent by 2020. These traffic and population factors argue for inclusion of Franklin County in the nonattainment area.

Of all the counties recommended for inclusion in the nonattainment area, Franklin County has the lowest total VOC emissions. This does not indicate that they are insignificant however. Franklin County has over two times the total VOC emissions as the Lincoln and Warren Counties. Franklin County also has significant total NOx emissions and ranks first in SOx emissions (approximately 28 percent of the total NOx emissions of the Missouri MSA). There are several large point sources located in Franklin County, and mobile emissions also play a significant role. All other counties considered, but not included, have significantly lower emissions. Emissions from Franklin County occur more distant that the other counties recommended for inclusion in the $PM_{2.5}$ nonattainment area, but these are closer than many other counties not recommended for inclusion. Overall, the total emissions located in Franklin County suggest that the area should be included in the nonattainment area.

<u>Conclusion</u>: Emissions, traffic, population trends, and connectivity are the most important factors that support the inclusion of Franklin County in the nonattainment area. Emissions from Franklin County are closer to the urban core than many counties under consideration. Emission rates in Franklin County also exceed those counties not included in the $PM_{2.5}$ nonattainment area recommendation. A strong case can be made that pollutants emitted in Franklin County do have a significant impact on the ambient monitors in the bi-state urban core. This is the fundamental test for inclusion.

In contrast, Franklin County is largely rural and the population density is not as high as the more urban counties. The rationale for including Franklin County in the $PM_{2.5}$ nonattainment area is substantive.

- **Jefferson County**

There is only one $PM_{2.5}$ monitor in Jefferson County. The Arnold monitor is located in the far northeast corner of the county, and the three year average for this monitor is 14.9 $\mu g/m^3$. This is very close to the standard, leading to the conclusion that local emissions are impacting this monitor. Having an average that close to the standard suggests that emissions from Jefferson County have an impact on the bi-state urban core, and should be included in the $PM_{2.5}$ nonattainment area.

Emissions from Jefferson County generally exceed those of Franklin. Of the Missouri MSA, Jefferson County is responsible for approximately 10 percent of the total VOC emissions (rank 4), 13 percent of the total NOx emissions (rank 4), 24 percent of the total SOx emissions (rank 3), and 21 percent of the total $PM_{2.5}$ emissions (rank 2). As discussed previously, when evaluating emissions and their impact on ambient $PM_{2.5}$ concentrations, it is important to recognize that the location and type of emissions have a significant influence on their impacts. Emissions from Jefferson County have a much more significant impact on the bi-state urban monitors than emissions from counties that are more distant. A review of the emission levels and emission profile of sources located in Jefferson County support inclusion of the Jefferson County in the $PM_{2.5}$ nonattainment area. Graphs in the Technical Support Document (pages 29-35) support this conclusion.

Much of the analysis of traffic, population and connectivity analysis of Franklin County can be applied to Jefferson County. The population in Jefferson County is not as dense as it is in St. Louis County, but it is denser than counties that are not being recommended for inclusion in the $PM_{2.5}$ nonattainment boundary. The population of the northern part is Jefferson County is much denser than the southern part of the county. There are pockets of urbanization, with most of the population located along major transportation corridors like Interstate 55. Much of the southern part of Jefferson County is rural. About 10 percent of the people living in the Missouri MSA live in Jefferson County, but much growth is expected. The population of Jefferson County is expected to increase by approximately 26 percent over the next 20 years. These population considerations also support inclusion of Jefferson County in the $PM_{2.5}$ nonattainment boundary.

Conclusion: Large point sources and significant total emissions clearly support inclusion of Jefferson County in the $PM_{2.5}$ nonattainment area. Traffic counts and connectivity and population trends also support inclusion. The relatively low population density and rural nature of southern Jefferson County are the two factors that mitigate this conclusion. Overall, there is sufficient technical justification to conclude that sources in Jefferson County do contribute to the $PM_{2.5}$ impacts in the bi-state urban core, and therefore this county should be included in the recommendation.

- **Lincoln and Warren Counties**

There are no $PM_{2.5}$ monitors located in Lincoln or Warren Counties. The primary question then becomes do these counties contribute to the $PM_{2.5}$ violations in the bi-state urban core.

Emissions are much lower in Lincoln and Warren County as compared to the other counties of the Missouri MSA. Together these counties are responsible for only 5 percent of the total VOC emissions of the Missouri MSA. These sources are significantly farther from the critical urban core monitors than the sources located in the other previously considered counties. Of the Missouri MSA, Lincoln and Warren together represent only 3 percent of the total NOx emissions, 0.3 percent of the total SOx emissions, and even though the counties are largely rural only a combined 16 percent of NH_3 emissions. The amount and distance of emissions do not support inclusion of these counties in the $PM_{2.5}$ nonattainment area.

There is significant connectivity, but the population of these counties and the population density of these counties are quite low. The combined population of Lincoln and Warren Counties is only an estimated 63, 469, which is approximately 3 percent of the total population of the Missouri MSA.

There are a couple of factors that argue for inclusion of Lincoln and Warren in the $PM_{2.5}$ nonattainment area. Interstate 70 goes through Warren County and is associated with significant VMT. The population of these counties is also expected to have dramatic growth over the next twenty years. Both of these points, however, are mitigated by the fact that the population is very low.

Conclusion: Although population growth and VMT on Interstate 70 are factors that support inclusion, the very low emission rates and the relatively large distance from the urban core eliminate Lincoln and Warren Counties from consideration as part of the $PM_{2.5}$ nonattainment area.

- **Surrounding Counties**

In general the population of the surrounding counties (St. Francois, Washington, Crawford, Pike, Ste. Genevieve, Gasconade, and Montgomery) is expected to have strong growth over the next twenty years. Emissions totals are generally quite low. For total VOC these counties range from only 1.6 percent (Montgomery County) of the total Missouri MSA up to only 4.1 percent (St. Francois County). Emissions of NOx are also generally low, and range from 0.84 percent (Washington County) of the Missouri MSA up to only 6.5 percent (Pike County). The same applies to emissions of SOx. SOx emissions from Crawford County are only 0.06 percent of the total Missouri MSA, with Pike County at 8.0 percent. In addition to the relatively low emission rates, it is important to note that these counties are much more distant from the urban core than the counties recommended for inclusion in the $PM_{2.5}$ nonattainment area. Overall population and population density are generally quite low as well. St. Francois County has the

highest population in this group of surrounding counties, with an estimated population of 55,641 (less than 3 percent of the total population of the Missouri MSA). On the other end of the spectrum Montgomery County has an estimated population of 12,136 (approximately 0.6 percent of the total Missouri MSA population). The population of most of these counties is expected to grow (with the exception of Pike County) over the next twenty years. This growth will not be significant enough to consider inclusion in the $PM_{2.5}$ nonattainment area.

There are a few specific points, however, that were considered that argue for inclusion. The department's Air Pollution Control Program has received several permit applications recently for large NOx sources to locate in Ste. Genevieve County. NOx, however, is not as great a concern as carbonaceous mass. As discussed previously the urban excess is dominated by carbonaceous mass. NOx and SOx emissions cannot be ignored, but they are not as great a concern in the urban core. Likewise, Pike County has some major sources as well, but again these are located quite a distance from the bi-state urban core.

With the exception of St. Francois County, much of the VMT in these surrounding counties are associated with interstate highways. There is generally much lower connectivity in these surrounding counties, than there is in the counties of the Missouri MSA. The non-point source emissions from the surrounding counties are very low in comparison to the Missouri MSA.

Conclusion: While there are a few large point sources located in the surrounding counties, the overall conclusion is that these counties do not contribute to violations of the $PM_{2.5}$ standard in the bi-state urban core. The population density and rural nature of these counties also clearly supports this conclusion.

TECHNICAL SUPPORT DOCUMENT FOR DETERMINATION OF NONATTAINMENT AREA BOUNDARIES IN MISSOURI FOR THE $PM_{2.5}$ NATIONAL AMBIENT AIR QUALITY STANDARDS

Missouri Department of Natural Resources

AIR POLLUTION CONTROL PROGRAM

October 2003

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1.0 INTRODUCTION

The United States Environmental Protection Agency (US EPA) promulgated air quality standards for airborne particulate matter smaller than 2.5 micrometers aerodynamic diameter ($PM_{2.5}$) in 1997 (62 Federal Register 38652, July 17, 1997). The standards are:

- 15 micrograms per cubic meter ($\mu g/m^3$), based on the 3-year average of annual arithmetic mean concentrations from single or multiple community-oriented monitors,

- 65 $\mu g/m^3$, based on the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area.

As required by the Clean Air Act, areas must be designated as attainment, nonattainment, or unclassifiable with respect to these standards. Implementation of these requirements has been delayed by legal proceedings, but is now expected to proceed on the following schedule:

1. September 2003, US EPA issues proposed $PM_{2.5}$ implementation rule,

2. February 15, 2004, State and Tribal recommendations due for designation of attainment and nonattainment areas,

3. July 2004, US EPA notifies States and Tribes concerning any modifications to their recommendations,

4. September 2004, US EPA issues final $PM_{2.5}$ implementation rule,

5. December 15, 2004, US EPA issues final $PM_{2.5}$ area designations,

6. December 2007, State implementation plans are due for $PM_{2.5}$ nonattainment areas,

7. December 2009-2014, Date for attainment of $PM_{2.5}$ standards (5 years after designation date, with a possible extension of up to 5 years).

This document provides technical support for the State of Missouri recommendations for designation of attainment and nonattainment areas (number 2 above).

On April 1, 2003 US EPA issued guidance for determining boundaries of $PM_{2.5}$ attainment and nonattainment areas. The guidance states that US EPA

> "...intend[s] to apply a presumption that the boundaries for urban nonattainment areas should be based on Metropolitan Area boundaries....These metropolitan areas provide presumptive boundaries for the geographic extent of urban areas."

The guidance also states that:

> "Boundaries used for implementation of the 8-hour ozone standard may also be an important factor in determining boundaries for $PM_{2.5}$ nonattainment areas."

If a State or Tribe believes that a Metropolitan Area does not appropriately represent a nonattainment area, the guidance lists nine factors that US EPA will consider in assessing recommendations for a nonattainment area that is not identical to (either larger or smaller than) a Metropolitan Area:

1. "Emissions in areas potentially included versus excluded from the nonattainment area,""
2. "Air quality in potentially included versus excluded areas,"
3. "Population density and degree of urbanization including commercial development in included versus excluded areas,"
4. "Traffic and commuting patterns,"
5. "Expected growth (including extent, pattern and rate of growth),"
6. "Meteorology (weather/transport patterns),"
7. "Geography/topography (mountain ranges or other air basin boundaries),"
8. "Jurisdictional boundaries (e.g., counties, air districts, Reservations, etc.),"
9. "Level of control of emission sources."

This document considers each of these factors in evaluating areas to be included in or excluded from the nonattainment area(s) in Missouri.

2.0 ST. LOUIS AREA INFORMATION

2.1 $PM_{2.5}$ AIR MONITORING RESULTS

There are sixteen Federal Reference Method monitoring sites in the St. Louis area. Fourteen are neighborhood scale and two are middle scale. The middle scale sites, Mound Street (St.) and VFW, are source oriented and not appropriate for comparison to the annual average national ambient air quality standard (NAAQS). In addition, there are four speciation sites and the St. Louis Supersite in East St. Louis, operated by Washington University, that provide detailed information on the different species of $PM_{2.5}$ in addition to total mass. Also, two continuous $PM_{2.5}$ monitors have been operated in the area, one at the Blair St. site in St. Louis and one at the St. Louis Supersite.

Annual Average

The $PM_{2.5}$ NAAQS annual standard is 15 $\mu g/m^3$. The annual standard is met when the 3-year average of annual arithmetic means is less than 15.05 $\mu g/m^3$, due to rounding. Annual averages for St. Louis area sites are shown in Table 2.1-1. Six sites, Blair St. in Missouri and Granite City, E. St. Louis, Alton, Wood River, and Swansea in Illinois, are in violation of the NAAQS annual standard, and South Broadway in Missouri may violate the standard when it completes three years of monitoring at the end of 2003. The remaining sites are near, but below, the standard. Unless there is a substantial increase in their annual concentration for several years, these sites will remain below the standard.

The spatial distribution map (Figure 2.1-1) shows a high concentration area, approximately 6 $\mu g/m^3$ above background, centered around Granite City and East St. Louis, with decreasing concentrations as distance from this area increases. Concentrations at the fringes of the urban area (Arnold, West Alton, and Swansea) are approximately 3 $\mu g/m^3$ above background levels measured at Mark Twain State Park. Concentrations at all of the Illinois sites are uniformly higher than Missouri sites at similar latitudes.

24-hour Average

The 24-hour standard is met when the 3-year average of the 98th percentile of daily $PM_{2.5}$ concentrations is less than or equal to 65 $\mu g/m^3$. For sites sampling everyday, the 98th percentile value is the eighth highest of the year. For sites sampling every third day, it is the third highest. As shown in Table 2.1-1, none of the St. Louis area sites are close to violating the 24-hour standard. In fact, there have been only three exceedances of the standard during the entire four-year history of the area network. On July 4, 2002, three sites in the St. Louis area recorded exceedances of the 24-hr standard. After examining continuous and speciation data from state sites and the St. Louis Supersite, it was

determined that fireworks displays, both public and private, likely contributed to these high levels.

There is a high degree of day-to-day concentration correlation between all sites except Granite City, which indicates these sites are affected by similar sources and meteorological effects, including regional, mobile, area, and point sources. Table 2.1-2 shows the correlation (R^2 values) for each pair of sites in the St. Louis area. When these correlations are averaged, excluding the Granite City site, a noticeable gap in R^2 values appears between Granite City and all other sites, including East St. Louis, which is nearby and has a three-year average nearly equal to that of Granite City.

Table 2.1-1. St. Louis Annual $PM_{2.5}$ Total Mass for 2000-2002

24-hr Std = 65 $\mu g/m^3$, 98th percentile **Annual Mean Std = 15.0 $\mu g/m^3$**

	98th percentile				**Annual Mean**			
Missouri	**2000**	**2001**	**2002**	**00-02**	**2000**	**2001**	**2002**	**00 - 02**
West Alton	34.4	36.5	35.0	**35.3**	14.8	15.0	14.2	**14.6**
Margaretta	33.5	33.7	35.5	**34.2**	14.8	14.3	14.5	**14.5**
Blair Street	34.8	34.0	36.5	**35.1**	16.0	15.3	15.4	**15.6**
Mound St.	35.6	33.8	35.9	**35.1**	**Middle scale site**			
S.Broadway	32.0	34.4	36.5	**34.3**	15.6*	14.8	15.3	**15.2******
Ferguson	33.3	32.7	38.4	**34.8**	14.3	13.4	13.5	**13.7**
Clayton	33.4	33.6	36.9	**34.6**	15.2	13.9	14.5	**14.5**
Sunset Hills		26.3	34.0	**30.2******	-	11.7*	13.0	**12.4**
Arnold	33.1	32.1	46.5	**37.2**	15.2	14.5	15.1	**14.9**
Illinois								
Alton	36.3	39.6	34.5	**36.8**	16.0	15.8	14.7	**15.5**
Wood River	32.1	33.9	33.9	**33.3**	15.9	14.9	15.1	**15.3**
VFW	37.4	42.9	44.6	**41.6**	**Middle scale site**			
Granite City	33.5	35.0	42.9	**37.1**	17.4	17.3	17.7	**17.5**
E. St. Louis	36.1	33.7	40.9	**36.9**	17.4	17.0	16.7	**17.0**
Swansea	32.8	39.3	37.2	**36.4**	15.0	15.5	15.1	**15.2**

* - less than four full quarters
** - less than three full years

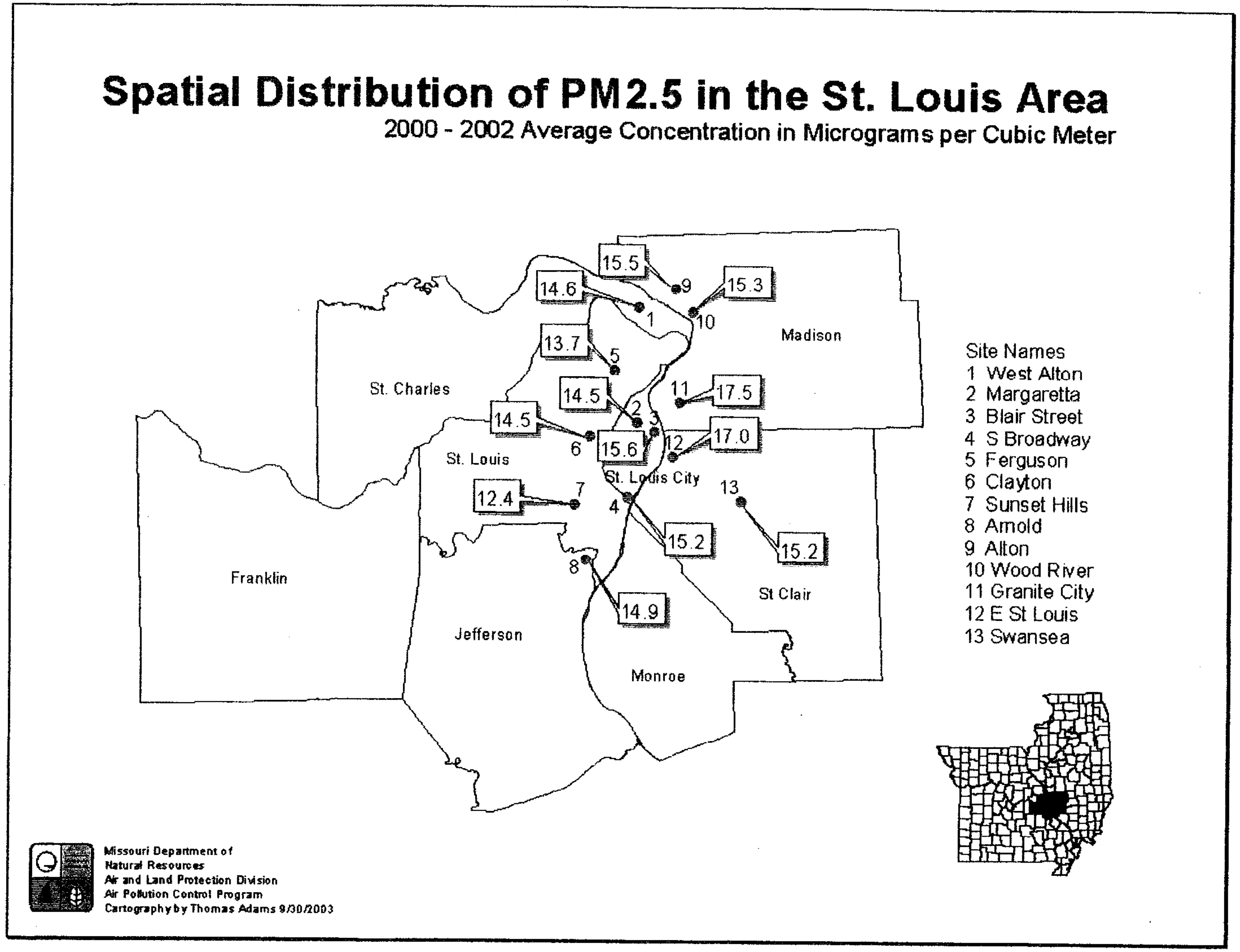


Figure 2.1-1. Spatial distribution of 2000-2002 average $PM_{2.5}$ in the St. Louis area.

Table 2.1-2. Correlation Coefficients for PM2.5 Measurements at St. Louis Area Sites													
	West Alton	Margaretta	Blair St.	South Broadway	Ferguson	Clayton AS	Sunset Hills	Arnold	Alton	Wood River	Granite City	East St. Louis	Swansea
W. Alton		0.874	0.873	0.853	0.918	0.811	0.878	0.834	0.879	0.773	0.680	0.704	0.738
Margaretta	0.874		0.963	0.957	0.932	0.862	0.930	0.908	0.832	0.781	0.688	0.801	0.758
Blair St.	0.873	0.963		0.949	0.921	0.862	0.940	0.905	0.825	0.766	0.691	0.787	0.757
S. Broadway	0.853	0.957	0.949		0.914	0.933	0.940	0.926	0.821	0.750	0.705	0.796	0.775
Ferguson	0.918	0.932	0.921	0.914		0.872	0.944	0.889	0.851	0.778	0.685	0.755	0.747
Clayton AS	0.811	0.862	0.862	0.933	0.872		0.935	0.845	0.753	0.715	0.643	0.703	0.702
Sunset Hills	0.878	0.930	0.940	0.940	0.944	0.935		0.968	0.762	0.764	0.667	0.784	0.805
Arnold	0.834	0.908	0.905	0.926	0.889	0.845	0.968		0.780	0.727	0.673	0.753	0.754
Alton	0.879	0.832	0.825	0.821	0.851	0.753	0.762	0.780		0.763	0.685	0.698	0.703
Wood River	0.773	0.781	0.766	0.750	0.778	0.715	0.764	0.727	0.763		0.686	0.704	0.643
Granite City													
E. St. Louis	0.704	0.801	0.787	0.796	0.755	0.703	0.784	0.753	0.698	0.704	0.654		0.690
Swansea	0.738	0.758	0.757	0.775	0.747	0.702	0.805	0.754	0.703	0.643	0.580	0.690	
Average*	0.830	0.872	0.868	0.874	0.866	0.817	0.877	0.844	0.788	0.742	0.670	0.743	0.734
*Average r2 with all other sites except Granite City													

2.2 $PM_{2.5}$ SPECIATION AND CONTINUOUS MONITOR RESULTS

In addition to measurement of $PM_{2.5}$ mass concentration, as discussed in Section 2.1, collection and analysis of chemical species in $PM_{2.5}$ particulate matter has been done at several sites in Missouri. Speciation analysis results, along with meteorological analysis, help in evaluating the contribution of emission sources to $PM_{2.5}$ mass concentrations.

In the St. Louis area, $PM_{2.5}$ speciation samplers have been operated on an every-third-day schedule at Blair St. since February 15, 2000 and at Arnold since April 13, 2001. A $PM_{2.5}$ speciation sampler was operated at Grant School from July 3, 2001 through June 25, 2002, on an every-sixth-day schedule with two periods of every-third-day sampling for special studies. $PM_{2.5}$ speciation samplers have also been operated on an every-third-day schedule at Liberty, near Kansas City, since January 20, 2002; and at Mingo Wildlife Refuge (reliably) since February 7, 2002; and every sixth day at Pleasant Green in central Missouri since October 5, 2002.

Figures 2.2-1, 2, and 3 show time series plots of major species concentrations (mass, sulfate, nitrate, ammonium, organic carbon, and elemental carbon measured at the three sites in the St. Louis area from April 2001 through April 2003. These figures support the following conclusions:

- Results at the three St. Louis area sites are well-correlated, both for total mass and for individual major species,
- Sulfate tends to be high in summer and contribute to summer mass peaks,
- Nitrate tends to be high in winter and contribute to winter mass peaks,
- Organic and elemental carbon peaks don't show as much seasonality, but tend to occur in the fall.

Examining time series plots of ratios of concentrations between sites can highlight differences between sites. Figures 2.2-4, 5, and 6 show time series plots of ratios of Grant School to Blair St. results and Arnold to Blair results for $PM_{2.5}$ mass, sulfate, nitrate, ammonium, organic carbon, and elemental carbon. These figures support the following conclusions:

- Sulfate ratios are close to one, suggesting that sulfate is widespread and/or results from distant sources,
- The nitrate ratio for Grant School to Blair St. is close to one, while the ratio for Arnold to Blair St. is less than one, suggesting either more nitrogen oxide emissions near Grant School or Blair St. than at Arnold or maximization of formation of secondary nitrate particulate matter in the region of the Grant School and Blair St. sites as compared to Arnold,

- Results for ammonium are similar to those for nitrate,

- Organic carbon ratios are close to one, but elemental carbon ratios are both less than one, suggesting more elemental carbon emissions near Blair St. than either Grant School or Arnold.

Quarterly average measurement results from these sites have been analyzed using the following assumptions, similar to those used in analyzing data from the Interagency Monitoring of Protected Visual Environment (IMPROVE) network: all sulfate is ammonium sulfate (a small amount may actually be uncombined sulfuric acid); all nitrate is ammonium nitrate, organic is organic carbon as reported with $PM_{2.5}$ data minus OCX, times 1.4; elemental carbon is elemental carbon as reported with $PM_{2.5}$ data plus OCX; and crustal includes Al, Si, Ca, Fe, Ti, each adjusted by a factor to account for oxides. The "other" category includes primarily metallic elements in addition to those included in the crustal category. This algorithm, in general, over-predicts total mass slightly, so species concentrations were then normalized to total mass.

Figure 2.2-7 shows the results of this analysis for Blair St. Results for Grant School and Arnold are very similar. As seen in the time series plots, the ammonium sulfate contribution to $PM_{2.5}$ mass concentration was highest in the third quarter (summer), and the ammonium nitrate contribution was highest in the first quarter (winter).

Comparison of speciation results for the Alton site in Illinois, generally downwind of St. Louis, to the Liberty site, generally downwind of Kansas City (Figure 2.2-8) shows that speciation results are similar between the two areas, but that every major species shows a slightly higher concentration downwind of St. Louis than downwind of Kansas City.

Although speciation results near Kansas City and near St. Louis are similar, St. Louis results do show differences in speciation from those in rural areas. A recent US EPA study (Venkatesh Rao et al., Chemical Speciation of $PM_{2.5}$ in Urban and Rural Areas, 2003) examines these differences for several US urban areas, including St. Louis, using data from IMPROVE (generally rural) and Speciation Trends Network (STN, generally urban) sites. This study used data for the period from March 2001 to February 2002. Species analyzed were sulfate, nitrate, ammonium (measured for STN, calculated stoichiometrically for IMPROVE), organic carbon, elemental carbon, and crustal elements as listed above. Because of systematic differences in organic and elemental carbon results from the two networks, only total carbonaceous mass was used in comparing urban and rural sites. Each urban site was paired with one or more rural sites. For St. Louis, measurements at three IMPROVE sites (Cadiz KY, Hercules Glade MO, and Bondville IL) were averaged based on inverse distance from St. Louis and used as a reference. Approximate urban excesses for St. Louis are as follows (values are approximate because some of them were estimated from graphs):

- $PM_{2.5}$ mass concentration, 5 $\mu g/m^3$ (rural background $PM_{2.5}$ mass concentration is 11 $\mu g/m^3$),

- Sulfate, 0.5 $\mu g/m^3$,
- Ammonium, 0.2 $\mu g/m^3$,
- Nitrate, 0.6 $\mu g/m^3$,
- Total carbonaceous mass, 2.5 to 3 $\mu g/m^3$,
- Crustal, 0.6 $\mu g/m^3$.

The urban excess for total carbonaceous mass is a range rather than a single value, because the factor used to convert organic carbon to organic compound mass is uncertain, so a range of 1.4 to 1.8 was used (a factor of 1.4 was used in the seasonal speciation data reported above). Also, there are differences in measurement of carbonaceous material between the STN and IMPROVE networks, so the difference in total carbonaceous mass is uncertain. Nevertheless, it appears that the greatest species contribution to urban excess is total carbonaceous mass.

Another study shows an urban excess $PM_{2.5}$ mass concentration of approximately 6 $\mu g/m^3$ and a rural background concentration of approximately 11 $\mu g/m^3$ (Lake Michigan Air Directors Consortium [LADCO], <u>$PM_{2.5}$ in the Upper Midwest</u>, June 2, 2003).

Estimates of the contributions of various major species to the urban excess can also be made using $PM_{2.5}$ speciation data from St. Louis and from rural areas in Missouri other than the IMPROVE sites used in the US EPA report referenced above. Figure 2.2-9 shows major species data for Blair St. and Mingo National Wildlife Refuge for multiple years, and for Blair St. and the Pleasant Green rural site in central Missouri for the perild of October 2002 through April 2003. Because the Pleasant Green site is relatively new, the second graph shows only fall, winter, and spring data and so is incomplete. The first graph suggests that nitrate and organics are the major contributors to urban excess; the second graph suggests that sulfate, organics, and elemental carbon are the major contributors. The common feature of these two graphs along with the results of the US EPA analysis summarized above is that carbonaceous material and possibly nitrate are the primary contributors to urban excess. This is consistent with the time series speciation results presented above, which show differences between St. Louis area sites for carbonaceous material and nitrate, but no significant differences for sulfate.

Continuous $PM_{2.5}$ measurements are available from the Blair St. site in St. Louis and the Tudor site (Supersite) in East St. Louis. Figure 2.2-10 shows the average hourly reading for high concentration days (daily average greater than 35 $\mu g/m^3$) at the Blair St. and Tudor sites and the average hourly reading for all days at Blair St. High concentration days resulting from anomalous conditions (July 4 and 5, 2002), readings of zero, and anomalous high hourly readings (possibly caused by moisture condensation, usually in the evening) were not included in the averages.

The figure shows a morning increase, greater at Tudor than at Blair St., which may result from morning traffic, and an evening increase, which may result from evening traffic and/or from increased nighttime meteorological stability. Other than the July 4 and 5 results, examination of continuous monitor results does not reveal other consistent features that might help in local source identification.

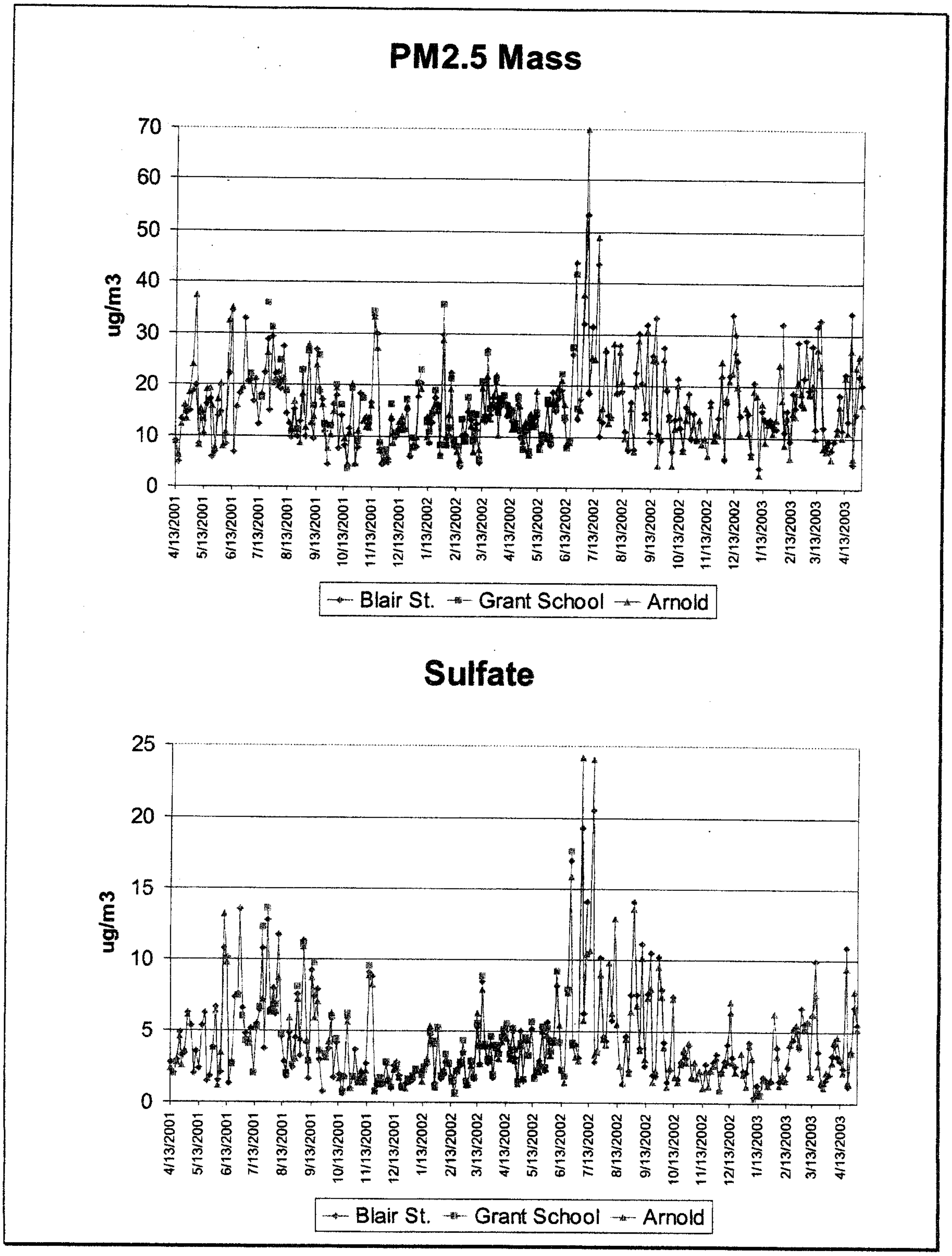


Figure 2.2-1. St. Louis area $PM_{2.5}$ speciation results, $PM_{2.5}$ mass and sulfate.

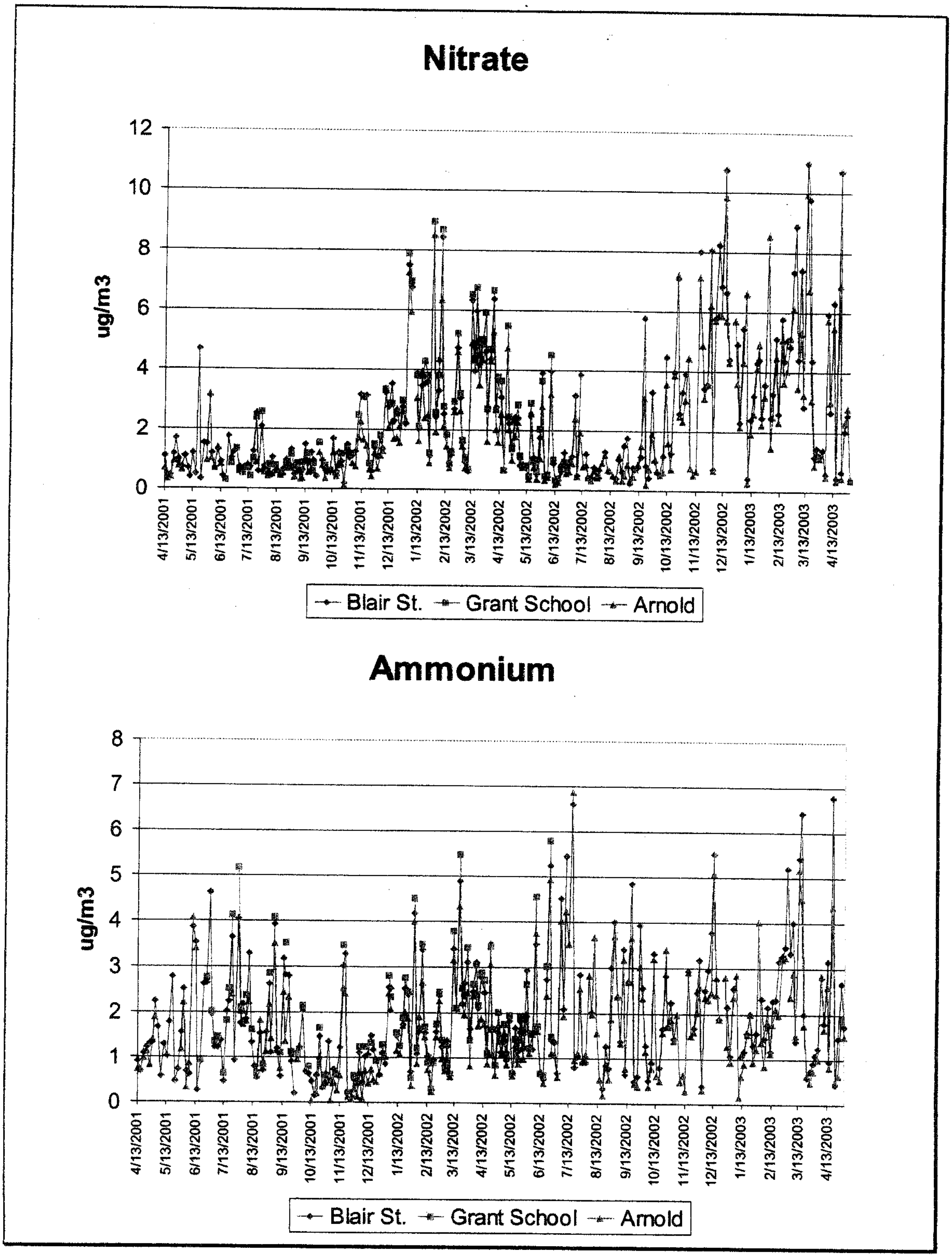


Figure 2.2-2. St. Louis area $PM_{2.5}$ speciation results, nitrate and ammonium.

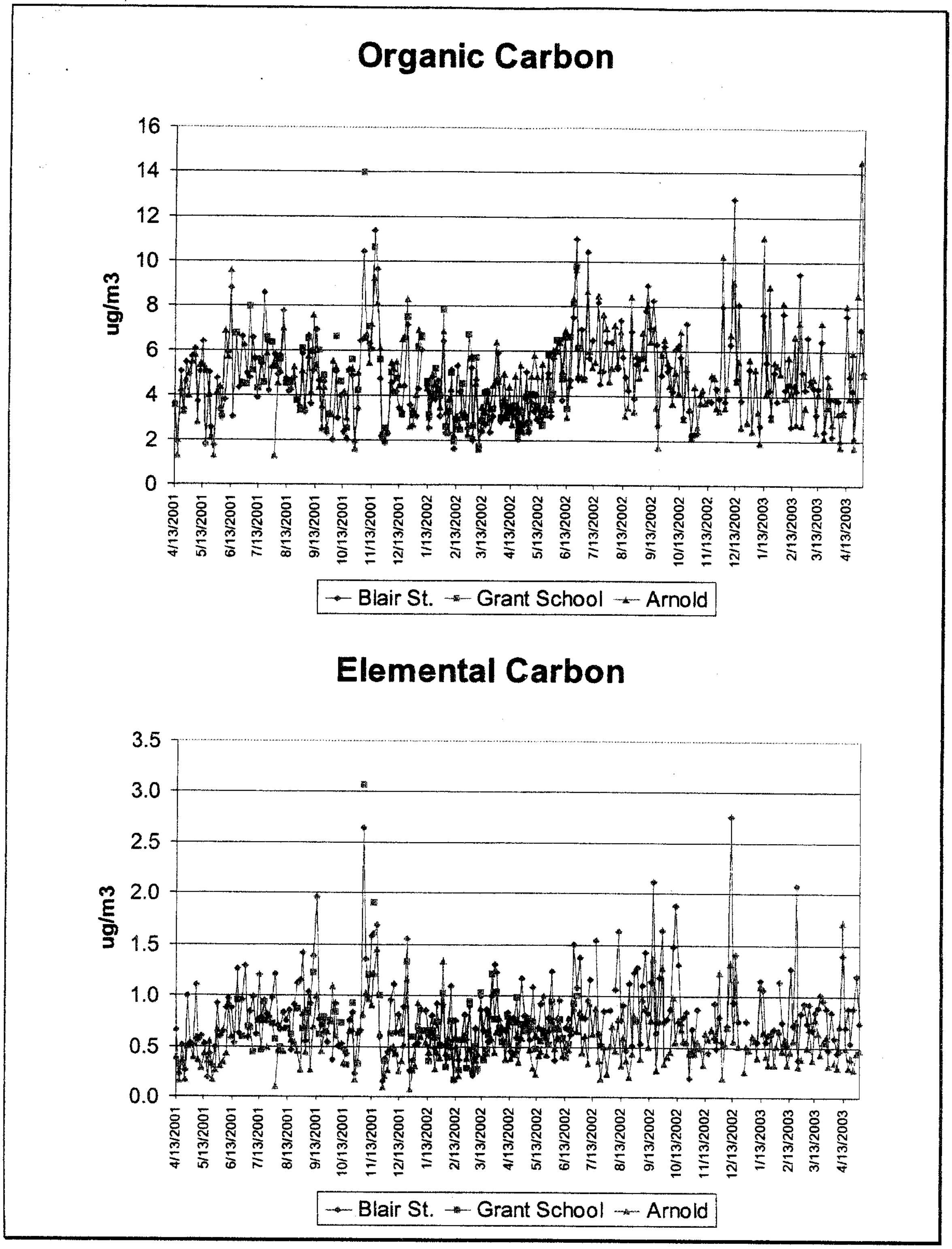


Figure 2.2-3. St. Louis area $PM_{2.5}$ speciation results, organic and elemental carbon.

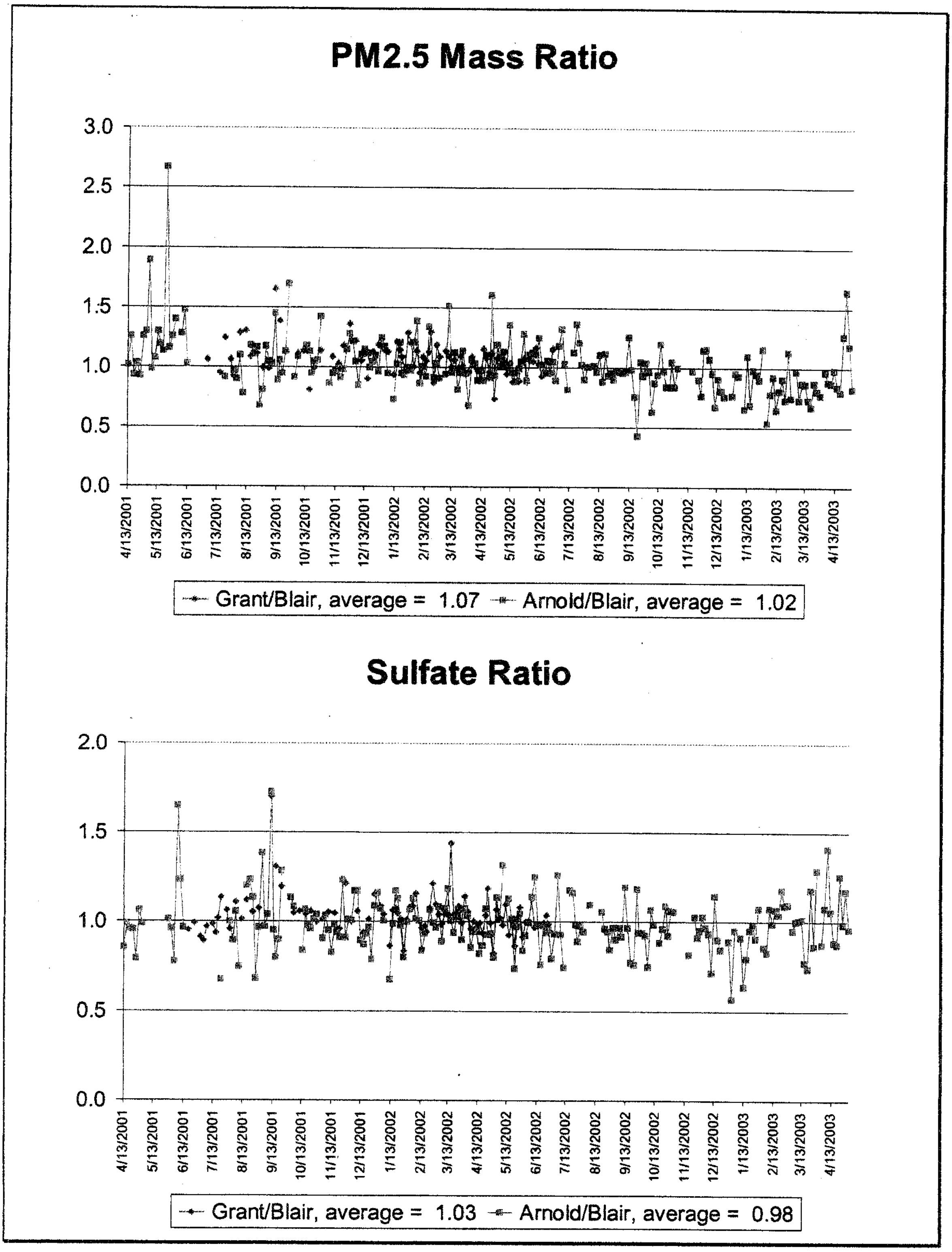


Figure 2.2-4. St. Louis area $PM_{2.5}$ speciation results, ratios of Grant School and Arnold to Blair St., $PM_{2.5}$ mass and sulfate.

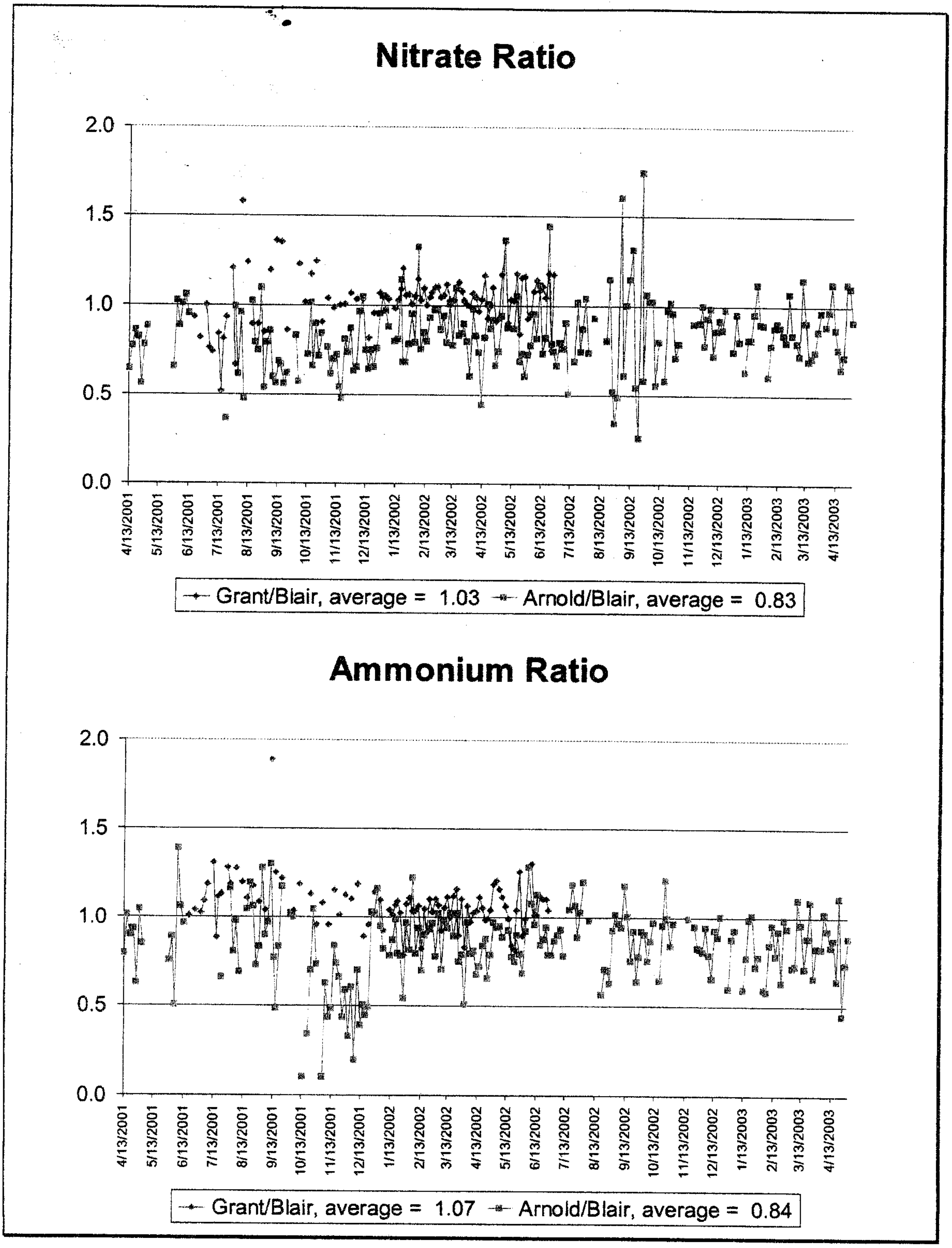


Figure 2.2-5. St. Louis area $PM_{2.5}$ speciation results, ratios of Grant School and Arnold to Blair St., nitrate and ammonium.

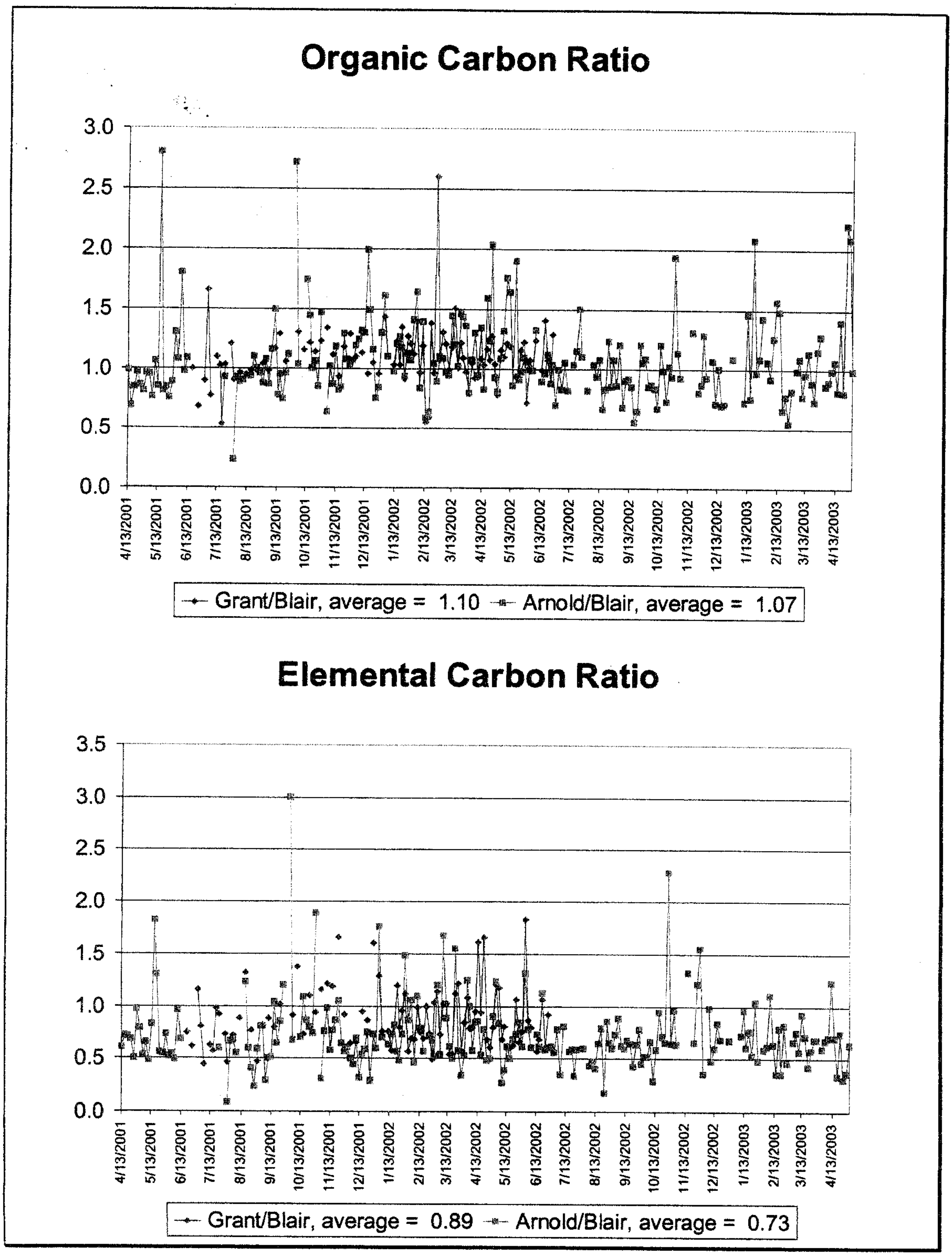


Figure 2.2-6. St. Louis area $PM_{2.5}$ speciation results, ratios of Grant School and Arnold to Blair St., organic and elemental carbon.

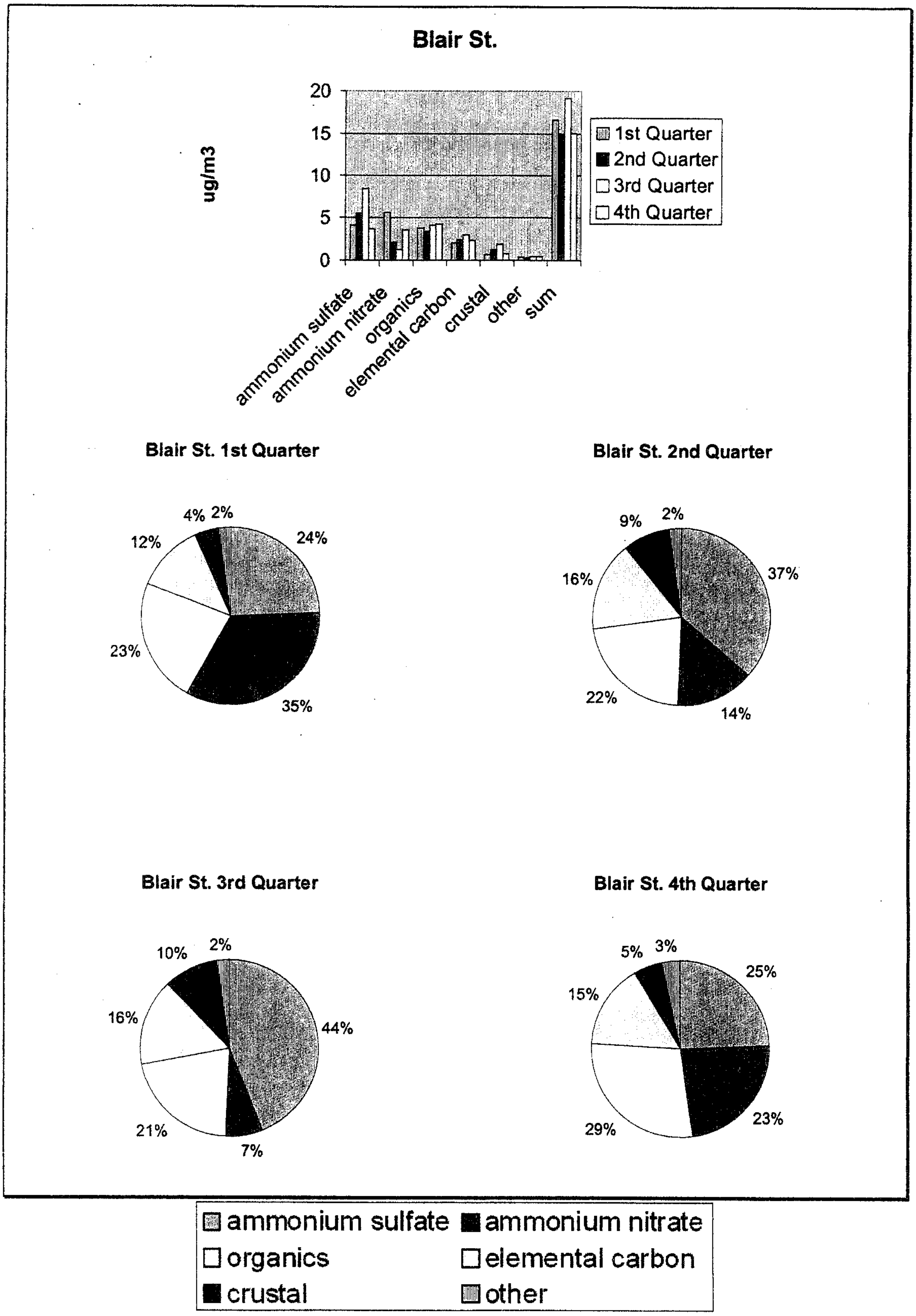


Figure 2.2-7. Blair Street seasonal $PM_{2.5}$ speciation results.

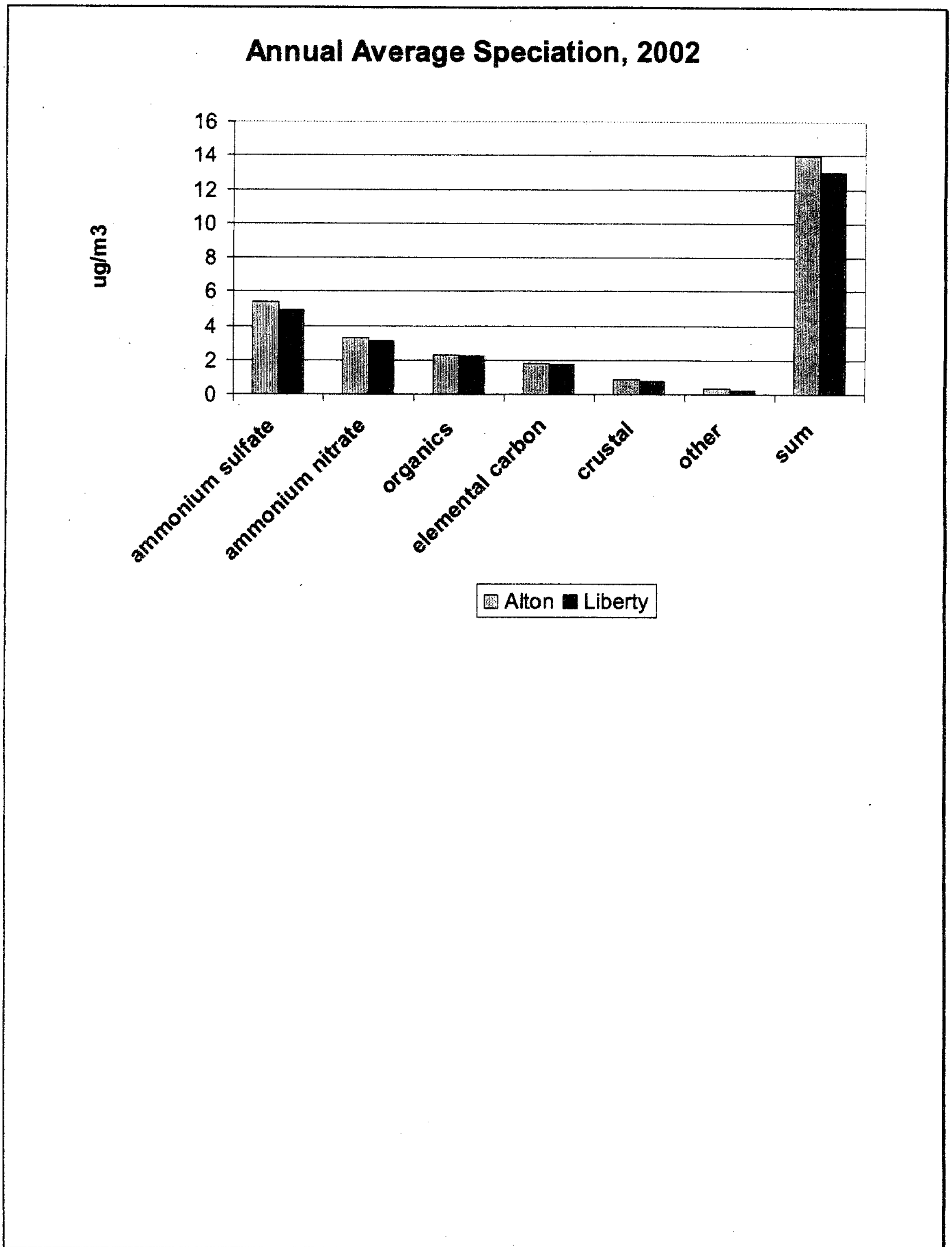


Figure 2.2-8. Comparison of $PM_{2.5}$ speciation results between Alton, downwind of St. Louis, and Liberty, downwind of Kansas City.

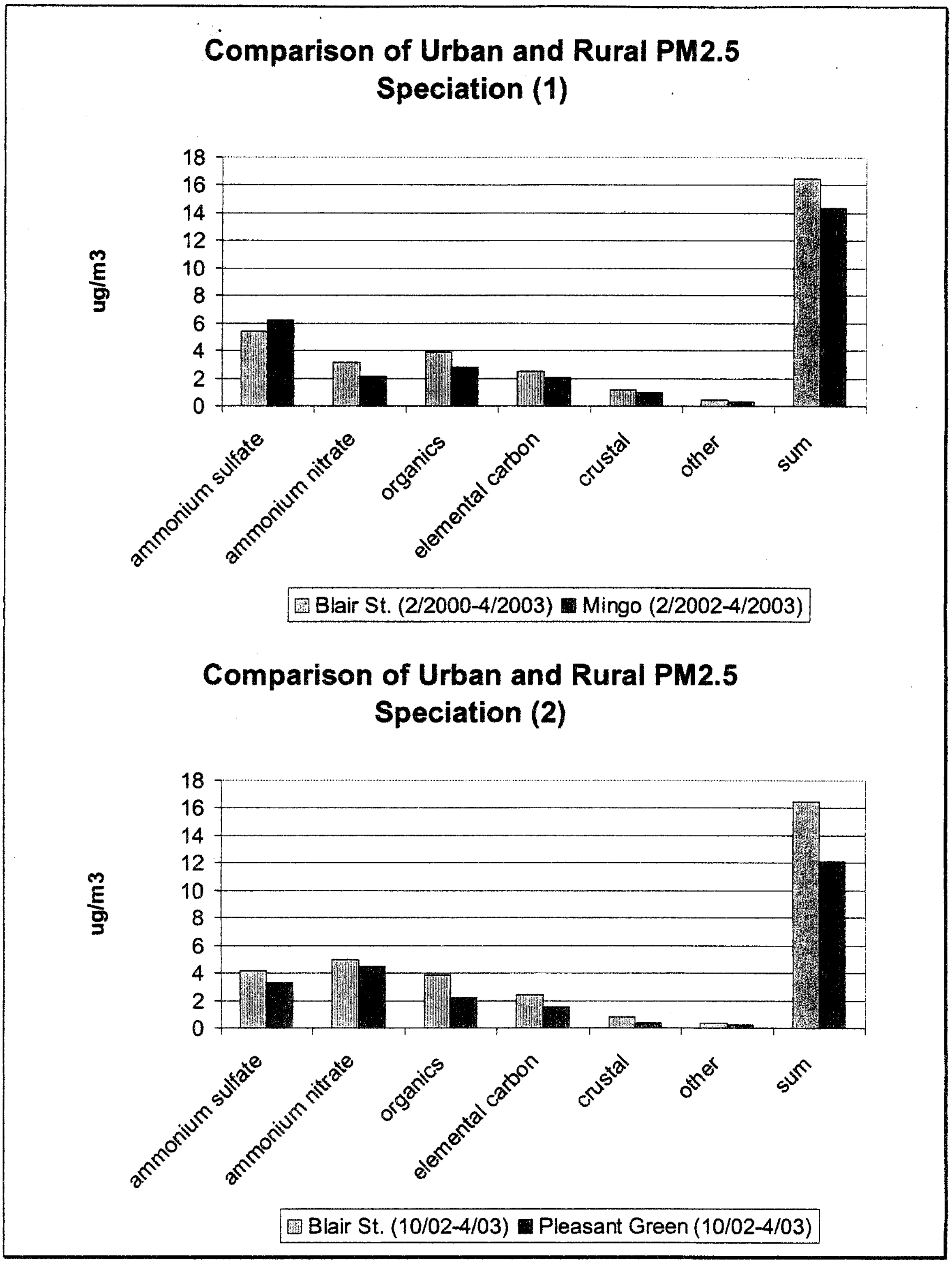


Figure 2.2-9. Comparisons of urban and rural $PM_{2.5}$ speciation results, Blair St. to Mingo and Blair St. to Pleasant Green.

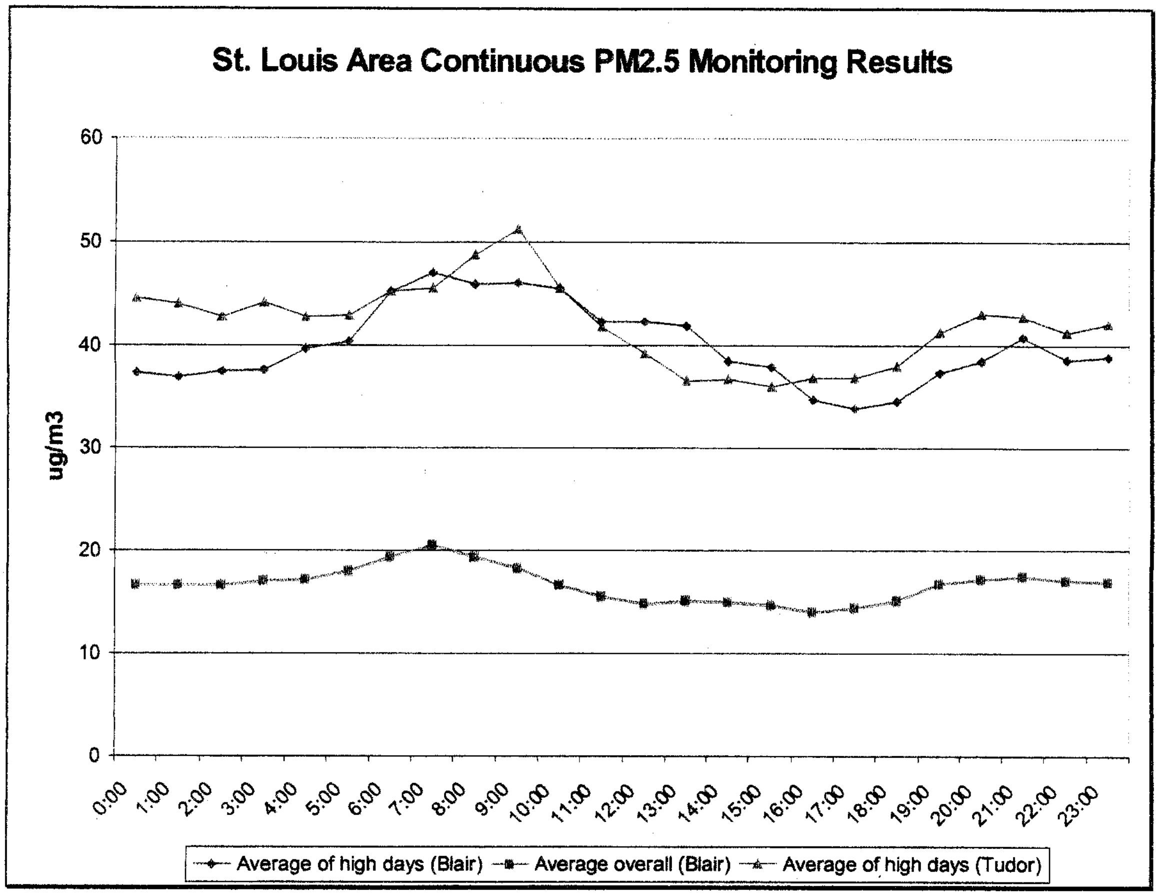


Figure 2.2-10. Average hourly $PM_{2.5}$ concentrations for high days (daily average greater than 35 $\mu g/m^3$) at the Blair St. and Tudor sites and average hourly $PM_{2.5}$ concentrations for all days at Blair St. (2002 and part of 2003 at Blair St., parts of 2001-2003 at Tudor).

2.3 EMISSION, POPULATION, AND TRAFFIC INFORMATION

2.3.1 Emission Inventory Data

Much airborne $PM_{2.5}$ is secondary, i.e., it is produced in the atmosphere by the combination of various pollutants -- oxides of sulfur (SO_x), oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and ammonia (NH_3). These pollutants are emitted from many of the same emission sources as precursors of ozone. For the St. Louis area $PM_{2.5}$ emission inventory, direct emissions of PM_{10}, $PM_{2.5}$, VOC, NO_x, SO_x, and NH_3 must therefore be considered. This information is shown in Table 2.3-1, based on the 1999 National Emission Inventory (NEI) *draft* Version 3, which provides the most recent complete data set of point, area, and mobile emissions for the Missouri and Illinois counties in and adjacent to the St. Louis MSA. Methodologies used by the EPA and APCP to determine emissions and quality assurance procedures are summarized for point, area, and mobile sources:

Point source emissions in the 1999 NEI are based on statewide facility Emissions Inventory Questionnaire (EIQ) submittals compiled in the Missouri Emission Inventory System (MoEIS). NEI emissions obtained from the EPA web site were verified by comparison to 1999 MoEIS data, and compared to 2000 through 2002 MoEIS data to identify where significant changes have occurred; the data were adjusted to reflect the most current actual emissions.

Area source emissions were estimated by the EPA and verified by comparison to Missouri area source emissions calculated for VOC and NO_x in the St. Louis Ozone Nonattainment Area. A number of new area source categories are included in the NEI for the first time, such as paved and unpaved roads, agricultural tilling, and construction. These have higher uncertainty than those of other source categories, as will be discussed in the $PM_{2.5}$ discussion below.

Mobile sources -- onroad motor vehicle emissions were estimated using the newly finalized MOBILE6 model. MOBILE6 calculates emissions by multiplying an appropriate emission factor in grams per mile by the corresponding vehicle miles traveled (VMT) and converts the product to units of tons of emissions. **Offroad motor vehicle emissions** were determined using the latest draft version of the NONROAD model to generate emission inventories for all gasoline, diesel, compressed natural gas (CNG), and liquefied petroleum gas (LPG) offroad equipment types. Supplemental methods were employed by the EPA to calculate emissions for aircraft, commercial marine vessels, and locomotives.

Pollutant Emission Profiles of St. Louis Area Counties

A comparison of emission sources and pollutant quantities in the counties in and adjacent to the St. Louis area helps to distinguish which counties are making significant contributions to elevated $PM_{2.5}$ levels.

$\underline{PM_{10}\text{ and }PM_{2.5}}$

Point, area, and on- and off-road county PM_{10} and $PM_{2.5}$ emissions are shown by county in the graphs in Figure 2.3-1 and 2.3-2; the pie charts show total emissions by county. The salient feature is that 94% of all PM_{10} and 83% of all $PM_{2.5}$ emissions are from area sources, dwarfing other sources of PM_{10} such as fuel combustion and mobile sources. Area sources of PM include paved and unpaved roads, agricultural tilling, construction, miscellaneous fugitive dust, forest wildfires, prescribed burning, and various other types of fugitive dust and open burning. 72% of all PM_{10} emissions are from just two area source categories - paved & unpaved road fugitive emissions.

The 1999 NEI tracks primary $PM_{2.5}$ emissions, which average 40% of ambient $PM_{2.5}$ overall, the rest being secondary $PM_{2.5}$, formed by the condensation of gaseous ammonia, sulfates, nitrates, and organics after their release from a source. Of the 40% which is primary emissions, about 80% are from area sources, mainly paved and unpaved roads, which are crustal (mineral) in composition. This feature of the inventory is not unique to the St. Louis area, but is characteristic of the 1999 NEI across the country. However, most crustal $PM_{2.5}$ doesn't travel far, it is released at ground level and may be removed by vegetation or deposited within a few kilometers of being emitted. Speciation measurements show that only about 2-3% of $PM_{2.5}$ in the Midwest is crustal materials, while 50 - 60% of the $PM_{2.5}$ captured on the filter is ammonium nitrate and sulfate, and the rest is organics and metals. We are working with the EPA to resolve these issues, and to focus on those sources of $PM_{2.5}$ involved in regional transport and responsible for adverse health effects.

Point, on-, and offroad sources generate only 16% of the estimated $PM_{2.5}$. Point sources in Jefferson, Franklin, and Ste. Genevieve Counties and in the City of St. Louis are the largest generators of primary $PM_{2.5}$, followed by mobile sources in St. Louis County and City. Some of the largest generators of primary $PM_{2.5}$ include electrical generation, coal, oil, and gas combustion, mineral products (cement kilns and lime processing), smelters, marine vessels, ferrous and nonferrous metals processing, followed by offroad and onroad motor vehicles in St. Louis County and City. However, $PM_{2.5}$ emission factors for many point, area, and mobile source categories are still in the process of being measured, so these emission estimates may change substantially.

$\underline{SO_2}$

SO_2 emissions are shown by county in Figure 2.3-3. The primary point sources are coal and oil combustion, most notably coal electrical generation. Industrial processes comprise the next greatest contributing group of point sources, the highest of these being non-ferrous metals (lead) processing and mineral products (cement kilns).

NO_X

NO_X emissions (Figure 2.3-4) are largely dominated by on- and offroad motor vehicles. Electrical generating, heating fuel, and industrial fuel combustion sources also have a significant impact.

VOCs

Numerous source categories contribute to the VOCs shown in Figure 2.3-5, particularly in St. Louis County. The highest emissions are estimated to be from light-duty gas cars and trucks, residential fireplaces, followed by consumer solvents, lawn and garden equipment, architectural surface coatings, pesticide application, and gasoline station Stage II transfers. There are various other smaller sources, the bulk of which fall under the overall category heading of area sources.

NH_3

Emission estimates for NH_3 (Figure 2.3-6) are very preliminary, tentative, and incomplete. According to the 1999 NEI, ammonia sources are primarily due to agricultural livestock and agricultural crops. Smaller significant sources are light-duty gasoline vehicles, sewage treatment (POTWs), and agricultural chemical manufacturing. Because Missouri EIQ inventories will not include ammonia until 2003, current point source emissions were obtained from the 2001 Toxic Release Inventory (TRI).

Total St. Louis Area Emissions

Total emissions for the 14 St. Louis area counties in Missouri are graphed in Figure 2.3-7. The five counties corresponding to the St. Louis area ozone nonattainment area account for 77.0% of emissions overall. Pike and Ste. Genevieve Counties have emissions intermediate between the metropolitan counties and the other rural counties, with 4.8% and 3.5% of the total St. Louis area emissions, respectively. The remaining rural counties display relatively low emissions, 14.7% for the seven counties combined.

Future St. Louis Area Emissions

Missouri has recently received several permit applications for large NO_x sources to the south of the St. Louis MSA. If all are approved, this will result in a net increase in NO_x emissions of approximately 9,000 tons per year, as well as higher SO_x, VOC, PM_{10}, and $PM_{2.5}$ emissions, as indicated in Table 2.3-1. The effect on future emissions overall is depicted in Figure 2.3-8. Ste. Genevieve County's emissions will increase to 5.3% of the total for the St. Louis area, slightly above the 4.7% level in Pike County.

Major Point Source Maps

Figures 2.3-9 through 12 are maps showing the locations of large emission point sources in the greater St. Louis area of Missouri of PM_{10}, SO_x, NO_x (greater than 100 tons per year), and VOC (greater than 25 tons per year). These maps reinforce the characterization of the five ozone nonattainment counties as the area where the majority of emission sources reside. Ste. Genevieve and Pike Counties have a significant number of major sources, which necessitates evaluation of these two counties in the process of recommending the definition of the $PM_{2.5}$ nonattainment area. The remaining rural Missouri counties contain a relatively small number of large point sources and uniformly low emissions overall.

Area-Specific Emission Controls

The St. Louis 1-hour ozone maintenance area (St. Louis City; St. Louis, St. Charles, Jefferson, Franklin, Madison (IL), Monroe (IL), and St. Clair (IL) Counties) has specific fuel requirements for control of VOC emissions. Since Missouri and Illinois opted into the federal reformulated gasoline program for the St. Louis area, reformulated gasoline (RFG) is required to be sold in these counties throughout the entire year, but lower volatility is required for RFG at terminals May 1 through September 15 and at retail stations June 1 through September 15. In addition, the St. Louis maintenance area has a vehicle inspection and maintenance program (Missouri 10 CSR 10-5.380). There are several other VOC point and area source regulations in place in the Missouri portion of the maintenance area:

1. open burning 10 CSR 10-5.070,
2. petroleum storage/transfer (Stage I/II) 10 CSR 10-5.220,
3. aerospace manufacturing/rework 10 CSR 10-5.295,
4. solvent metal cleaning 10 CSR 10-5.300,
5. liquified cutback asphalt 10 CSR 10-5.310,
6. industrial surface coating 10 CSR 10-5.330,
7. rotogravure/flexographic printing 10 CSR 10-5.340,
8. synthesized pharmaceutical products 10 CSR 10-5.350,
9. polyethylene bag sealing operations 10 CSR 10-5.360,
10. application of deadeners and adhesives 10 CSR 10-5.370,
11. manufacturing of paint, laquer, varnish, enamels 10 CSR 10-5.390,
12. manufacturing of polystyrene resins 10 CSR 10-5.410,
13. equipment leaks from synthetic organic/polymer manufacturing 10 CSR 10-5.420,
14. bakery ovens 10 CSR 10-5.440,
15. offset lithographic printing 10 CSR 10-5.442,
16. traffic coatings 10 CSR 10-5.450,
17. aluminum foil rolling 10 CSR 10-5.451,
18. solvent cleanup operations 10 CSR 10-5.455,
19. municipal solid waste landfills 10 CSR 10-5.490,
20. volatile organic liquid storage 10 CSR 10-5.500,

21. existing major sources (RACT fixups) 10 CSR 10-5.520,
22. wood furniture manufacturing 10 CSR 10-5.530,
23. batch process operations 10 CSR 10-5.540,
24. reactor and distillation processes for synthetic organic chemical manufacture 10 CSR 10-5.550.

Also, Missouri has a NO_x RACT rule (10 CSR 10-5.510) for major NO_x sources in the St. Louis area. Missouri is committed to implement NO_x reduction requirements under the state rule 10 CSR 10-6.350 entitled "Emission Limitations and Emissions Trading of Oxides of Nitrogen." It establishes emission limitation on electric generating units (EGUs). EGUs in the eastern one-third of the state are subject to 0.25 lbs NO_x /MMBTU heat input emission limitation. The State of Illinois has been included in the NOx SIP call and EGU control will be set at 0.15 lb/MMBTU in the trading program.

Table 2.3-1: 1999 - 2001 Emission Inventory for Missouri and Illinois (MSA) Counties in the St. Louis Area

	VOC (TPY)				NO_X (TPY)				SO_X (TPY)			
MISSOURI:	POINT	AREA	MOBILE	TOTAL	POINT	AREA	MOBILE	TOTAL	POINT	AREA	MOBILE	TOTAL
ST. LOUIS	3,939.3	19,767.5	30,673.9	54,380.7	8,612.4	6,228.6	42,044.0	56,885.0	14,843.8	5,479.3	2,325.2	22,648.2
ST. LOUIS CITY	4,067.9	7,117.4	10,101.7	21,286.9	2,691.6	2,760.6	23,423.4	28,875.6	8,516.8	3,716.2	2,121.6	14,354.6
ST. CHARLES	1,502.5	6,835.9	7,268.6	15,607.0	14,566.4	1,132.3	10,421.2	26,119.9	43,774.8	348.4	608.6	44,731.8
JEFFERSON	789.6	5,778.4	5,378.5	11,946.5	9,198.1	677.3	9,370.4	19,245.8	39,281.9	640.4	505.5	40,427.8
FRANKLIN	816.3	4,984.2	2,965.0	8,765.5	7,870.8	813.4	6,924.8	15,608.9	47,612.7	694.1	312.1	48,618.8
LINCOLN	64.1	2,138.4	1,361.6	3,564.0	77.8	150.4	2,736.1	2,964.3	12.2	28.8	179.3	220.2
WARREN	105.5	1,903.0	938.5	2,947.0	0.6	181.5	1,728.2	1,910.3	0.0	224.2	91.0	315.2
Missouri MSA	**11,285.1**	**48,524.8**	**58,687.7**	**118,497.6**	**43,017.6**	**11,944.1**	**96,648.1**	**151,609.8**	**154,042.0**	**11,131.3**	**6,143.2**	**171,316.4**
St. Francois	72.3	3,198.9	1,534.8	4,806.0	317.4	1,835.9	2,218.7	4,371.9	39.8	549.2	94.1	683.1
Washington	46.4	2,661.7	678.0	3,386.1	24.7	109.2	1,137.3	1,271.2	2.9	100.5	46.5	149.9
Crawford	110.4	2,533.2	1,317.4	3,961.1	3.5	176.4	2,121.7	2,301.7	0.1	21.6	89.5	111.2
Pike	1,874.0	2,011.8	778.7	4,664.5	7,871.6	159.2	1,827.5	9,858.2	13,428.8	61.7	187.1	13,677.5
Ste. Genevieve	172.3	1,292.2	1,005.2	2,463.9	4,742.0	177.4	2,532.3	7,451.7	7,683.7	122.9	201.4	8,008.0
Ste. Genevieve (Growth)	920.3	1,292.2	1,005.2	3,217.7	13,542.0	177.4	2,532.3	16,251.7	10,724.7	122.9	201.4	11,049.0
Gasconade	19.5	1,740.5	585.1	2,345.1	47.3	134.3	1,969.2	2,150.8	0.7	140.1	101.3	242.2
Montgomery	2.8	1,185.9	697.7	1,886.4	111.3	93.1	1,602.2	1,806.6	196.9	60.1	83.2	340.2
ILLINOIS:												
CLINTON	180.2	1,046.5	1,211.5	2,438.2	1,302.0	124.2	2,367.6	3,793.7	362.6	104.9	138.0	605.5
JERSEY	17.6	593.4	619.8	1,230.7	0.0	72.6	1,757.9	1,830.5	0.0	44.5	200.5	245.0
MADISON	5,265.0	7,690.3	7,021.6	19,976.9	27,138.2	599.4	11,054.9	38,792.5	65,775.7	274.5	615.9	66,666.0
MONROE	37.8	675.5	779.8	1,493.1	10.3	65.8	2,398.8	2,474.9	0.0	15.8	229.2	245.0
ST. CLAIR	1,579.6	5,715.0	6,964.1	14,258.7	770.2	599.9	10,806.3	12,176.5	3,193.2	263.6	663.1	4,119.8
Illinois MSA	**7,080.1**	**15,720.7**	**16,596.7**	**39,397.5**	**29,220.7**	**1,461.8**	**28,385.6**	**59,068.1**	**69,331.6**	**703.2**	**1,846.7**	**71,881.4**
MSA Total	**18,365.2**	**64,245.5**	**75,284.4**	**157,895.1**	**72,238.3**	**13,405.9**	**125,033.7**	**210,677.9**	**223,373.6**	**11,834.4**	**7,989.8**	**243,197.8**

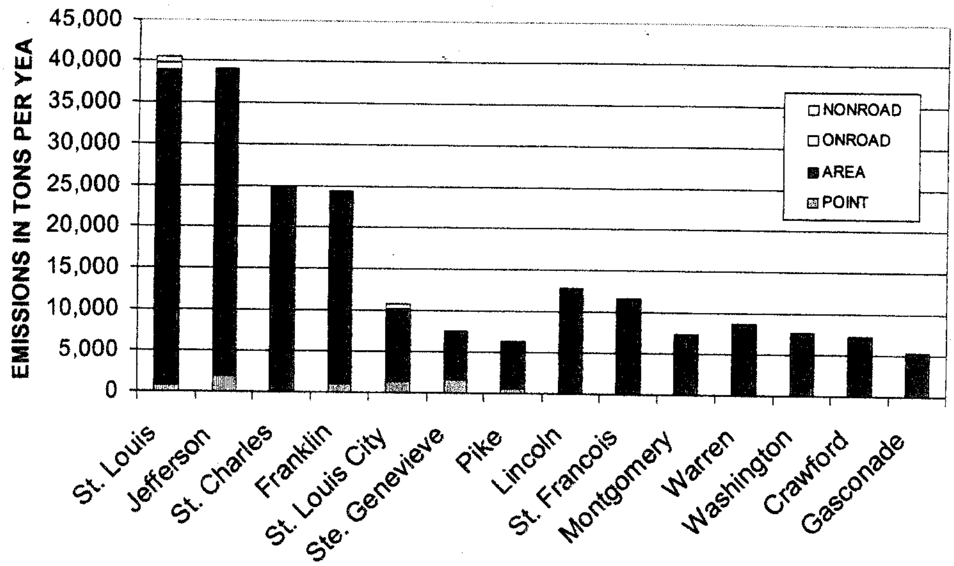
Key:
COUNTY - Counties in the Ozone 1-Hour Nonattainment Area
COUNTY - Counties in MSA
County - Additional Counties

Table 2.3-1 ***(Continued)*** **: 1999 - 2001 Emission Inventory for Missouri and Illinois (MSA) Counties in the St. Louis Area**

	PM_{10} (TPY)				$PM_{2.5}$ (TPY)				NH3 (TPY)			
MISSOURI:	POINT	AREA	MOBILE	TOTAL	POINT	AREA	MOBILE	TOTAL	POINT	AREA	MOBILE	TOTAL
ST. LOUIS	678.1	38,135.1	1,619.7	40,432.9	379.7	11,215.5	1,327.7	12,922.9	5.7	2,192.5	1,324.1	3,519.1
ST. LOUIS CITY	1,333.5	8,574.2	843.6	10,751.3	757.5	2,568.5	718.5	4,044.5	7.6	24.8	492.4	519.3
ST. CHARLES	116.9	24,276.6	457.3	24,850.8	74.2	5,188.4	383.0	5,645.6	15.2	653.6	294.1	948.5
JEFFERSON	1,863.7	36,713.0	345.9	38,922.6	1,274.3	6,851.7	283.8	8,409.8	2.7	379.5	247.7	4,378.8
FRANKLIN	1,013.6	23,102.1	248.9	24,364.6	702.0	4,205.3	209.4	5,116.6	0.0	2,405.2	142.7	2,550.5
LINCOLN	89.7	12,644.7	131.0	12,865.3	49.4	2,230.3	113.4	2,393.1	0.0	1,376.2	48.0	1,424.2
WARREN	6.4	8,603.9	77.5	8,687.7	5.2	1,598.3	66.3	1,669.8	0.0	781.7	35.4	817.1
Missouri MSA	**5,101.8**	**152,049.6**	**3,723.9**	**160,875.3**	**3,242.3**	**33,857.8**	**3,102.1**	**40,202.3**	**31.2**	**7,813.5**	**2,584.4**	**14,157.5**
St. Francois	118.8	11,441.7	81.6	11,642.1	62.3	2,173.7	66.6	2,302.6	0.0	752.1	63.0	815.1
Washington	26.8	7,588.0	43.3	7,658.2	13.2	1,323.5	35.7	1,372.3	0.0	603.9	28.4	632.3
Crawford	56.2	7,033.9	75.7	7,165.8	49.5	1,259.7	62.8	1,371.9	0.0	743.4	46.7	790.1
Pike	535.0	5,639.0	114.2	6,288.1	350.0	1,030.1	102.7	1,482.8	61.5	1,358.7	17.2	1,376.0
Ste. Genevieve	1,655.0	5,804.1	102.2	7,561.3	1,304.4	1,047.1	88.2	2,439.7	0.0	993.9	41.3	1,035.7
Ste. Genevieve (Growth)	2,728.0	5,804.1	102.2	8,634.3	2,377.4	1,047.1	88.2	3,512.7	0.0	993.9	41.3	1,035.7
Gasconade	3.4	5,272.7	74.8	5,350.8	1.8	922.3	65.7	989.8	0.0	1,402.2	19.7	1,421.9
Montgomery	59.8	7,246.3	77.9	7,384.0	25.0	1,309.9	67.5	1,402.5	0.0	1,378.7	29.8	1,408.6
ILLINOIS:												
CLINTON	59.8	8,054.7	127.2	8,241.6	29.3	1,601.0	111.2	1,741.6	0.0	2,528.8	40.3	2,569.0
JERSEY	28.5	4,587.5	95.6	4,711.6	9.7	925.9	85.1	1,020.7	0.0	500.3	20.9	521.2
MADISON	5,286.8	13,312.8	440.1	19,039.7	4,240.8	2,823.0	366.4	7,430.2	1,047.3	1,226.7	300.8	2,574.8
MONROE	64.5	5,164.4	114.4	5,343.3	22.9	1,057.2	101.1	1,181.2	0.0	938.9	27.9	966.8
ST. CLAIR	1,140.3	13,026.6	427.4	14,594.3	827.7	3,007.9	352.3	4,187.9	9.3	1,048.5	297.7	1,355.4
Illinois MSA	**6,579.8**	**44,146.1**	**1,204.6**	**51,930.4**	**5,130.4**	**9,415.0**	**1,016.2**	**15,561.6**	**1,056.6**	**6,243.2**	**687.5**	**7,987.2**
MSA Total	**11,681.6**	**196,195.6**	**4,928.5**	**212,805.7**	**8,372.7**	**43,272.8**	**4,118.4**	**55,763.9**	**1,087.8**	**14,056.6**	**3,271.9**	**22,144.7**

Key:
COUNTY - Counties in the 0zone 1-Hour Nonattainment Area
COUNTY - Counties in MSA
County - Additional Counties

Figure 2.3-1. PM_{10} EMISSIONS IN THE ST. LOUIS AREA



PM10 Total Emissions

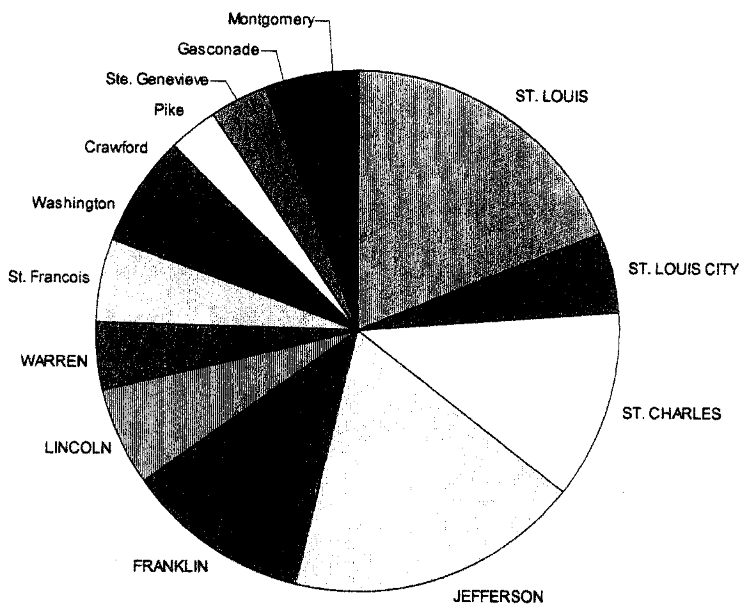
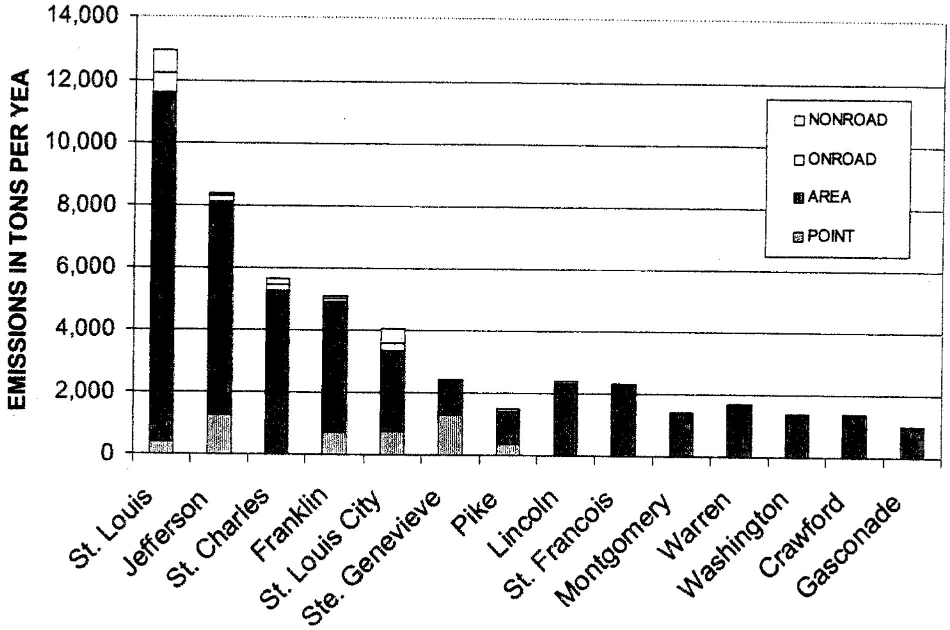


Figure 2.3-2. $PM_{2.5}$ EMISSIONS IN THE ST. LOUIS AREA



PM2.5 Total Emissions

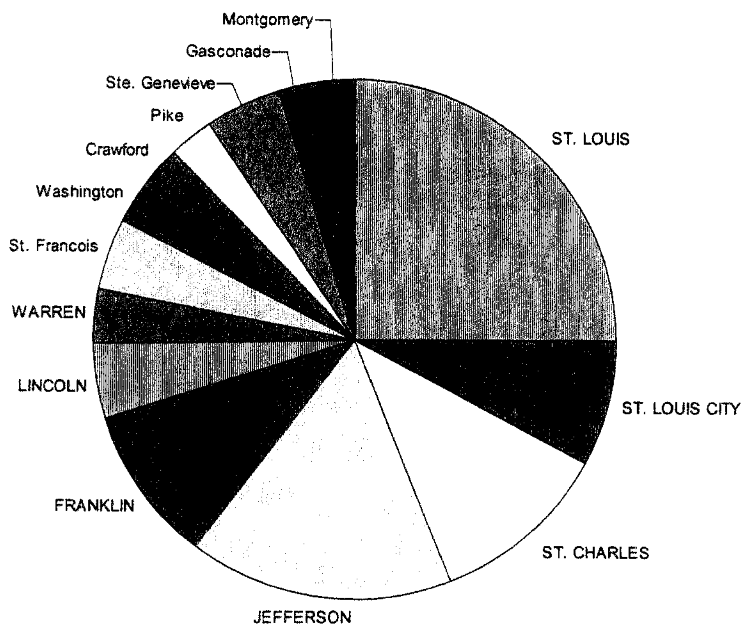


Figure 2.3-3. SO_2 EMISSIONS IN THE ST. LOUIS AREA

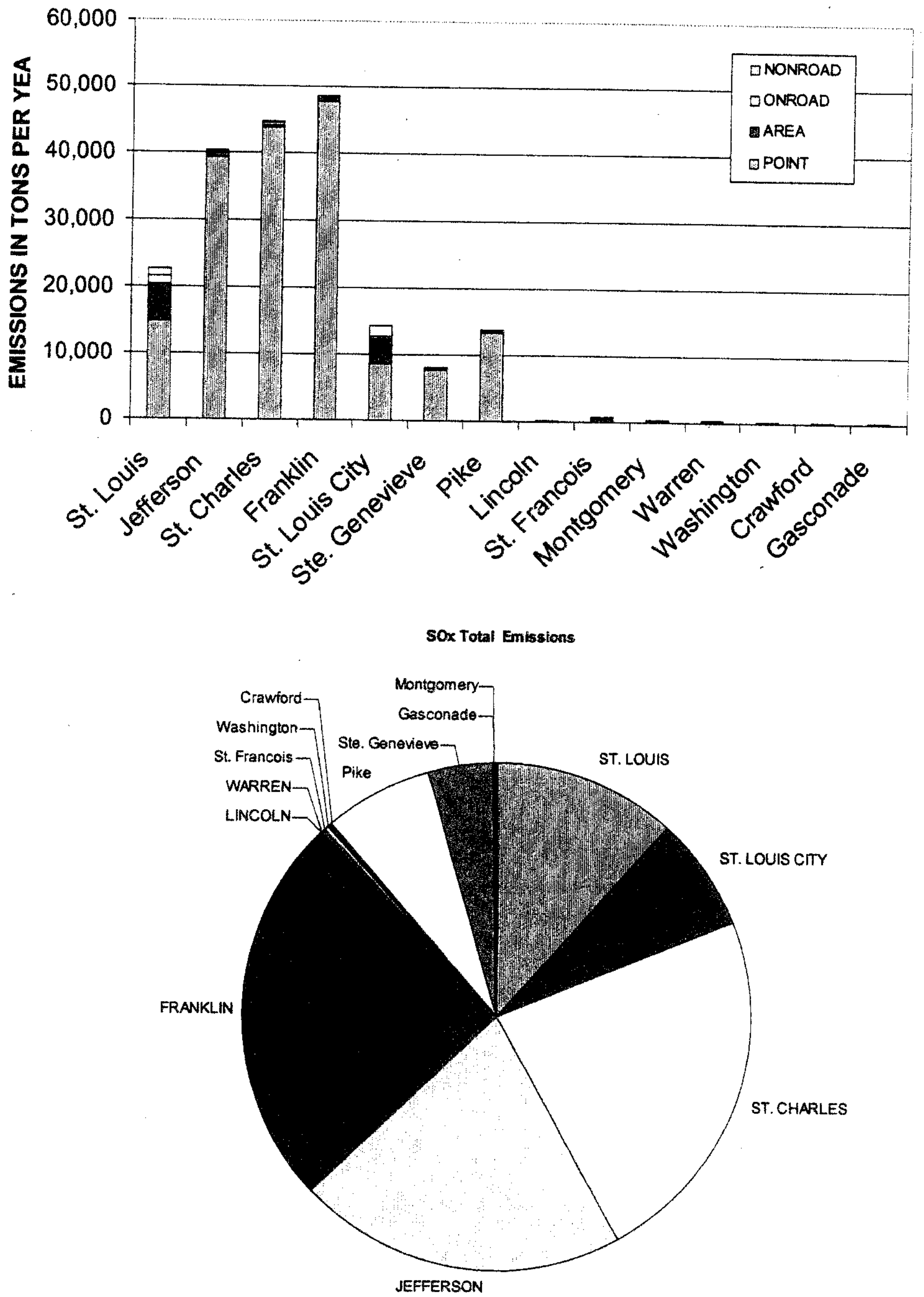
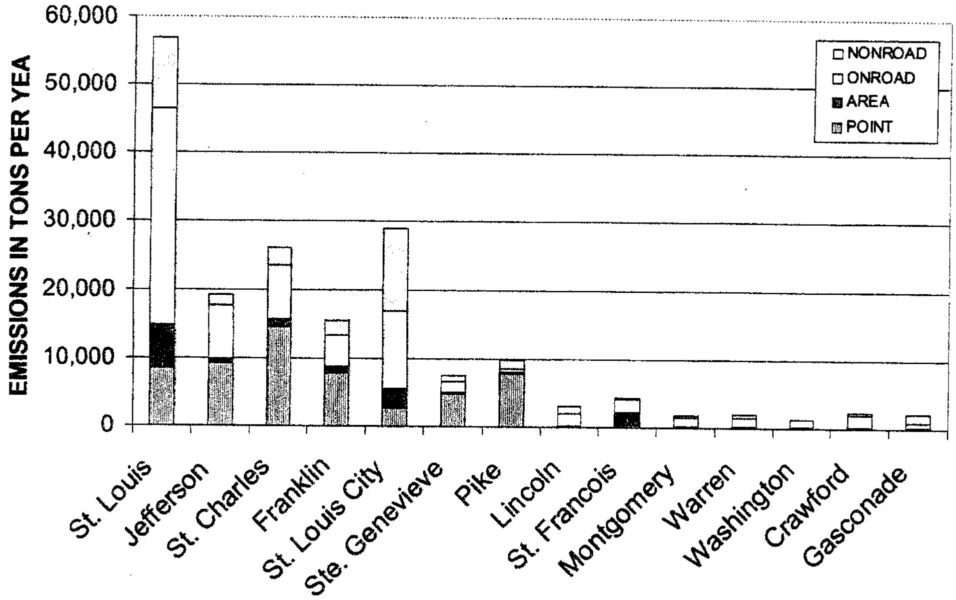


Figure 2.3-4. NO$_X$ EMISSIONS IN THE ST. LOUIS AREA



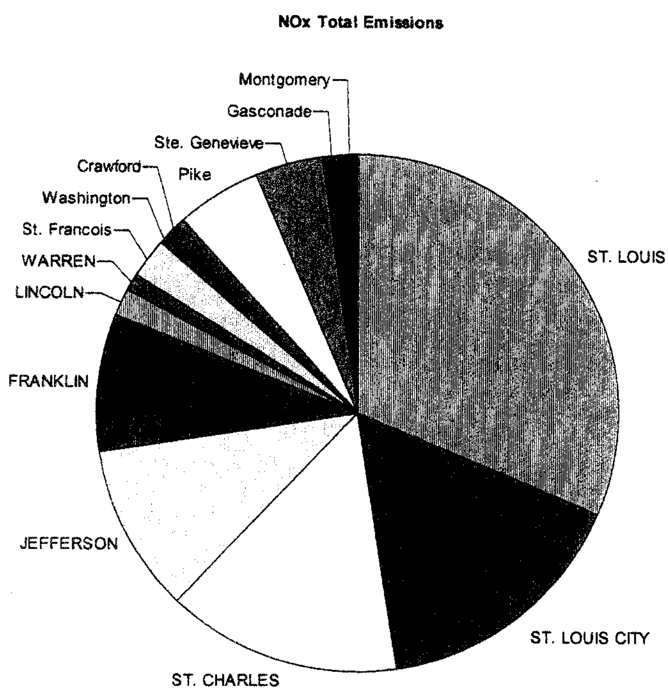
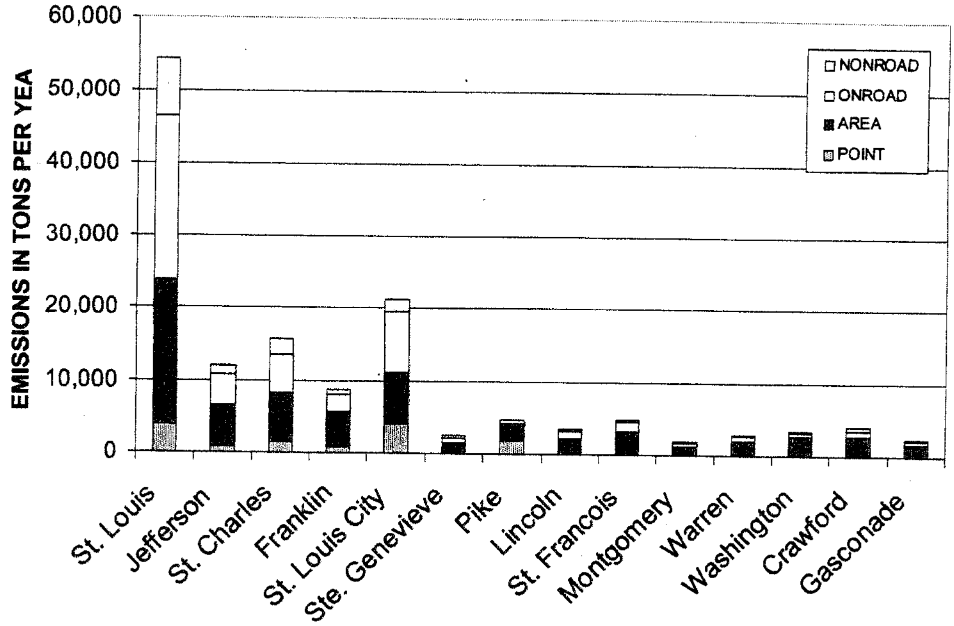
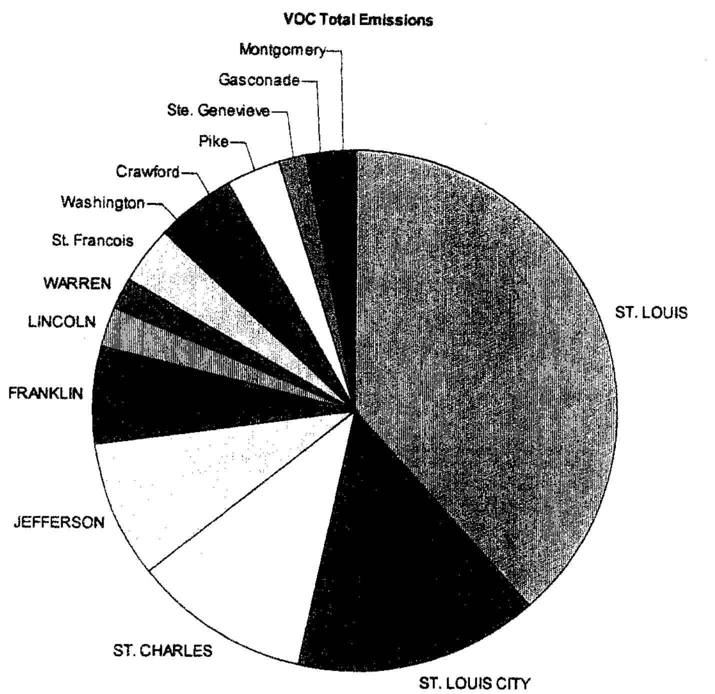


Figure 2.3-5. VOC EMISSIONS IN THE ST. LOUIS AREA





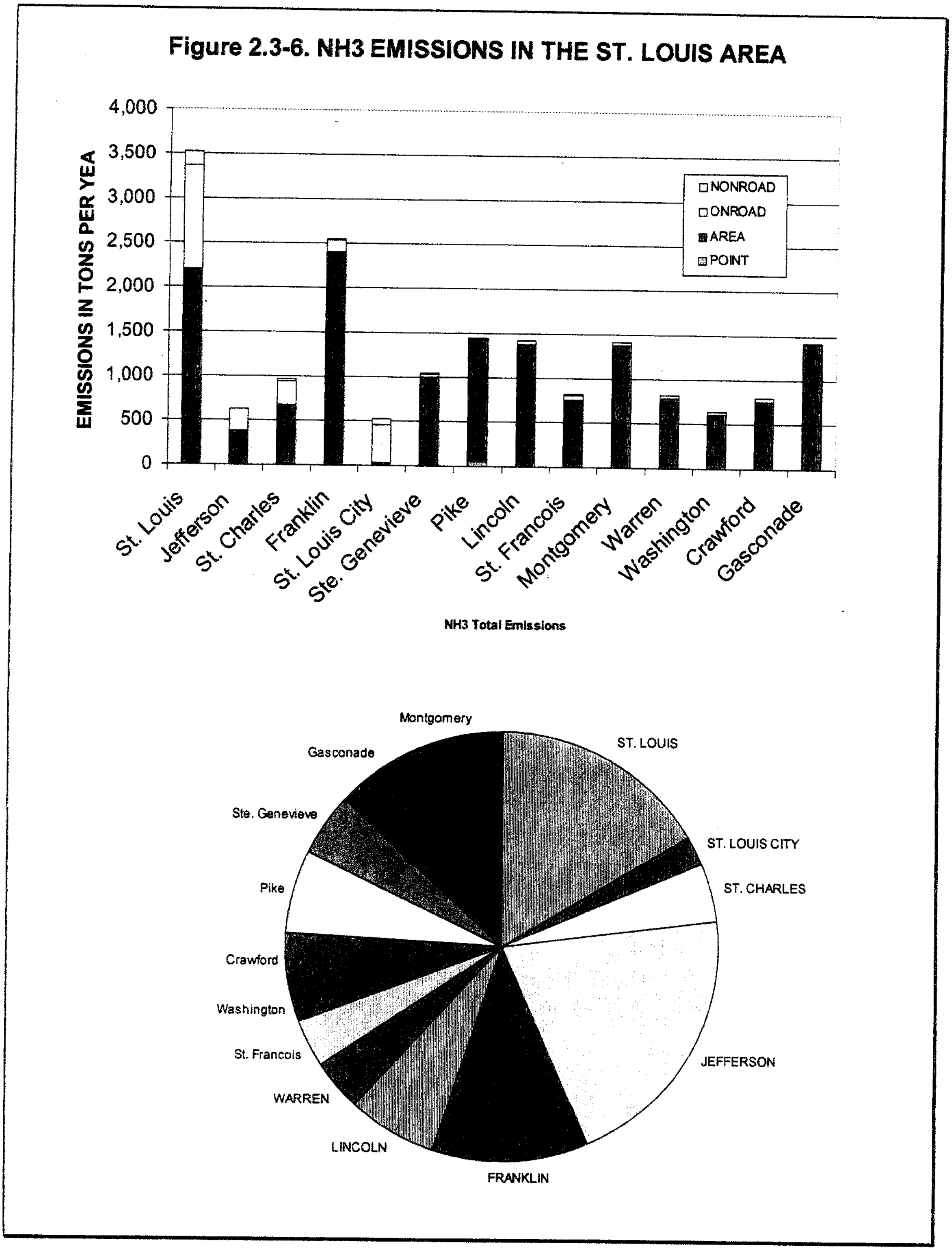


Figure 2.3-6. NH3 EMISSIONS IN THE ST. LOUIS AREA
EMISSIONS IN TONS PER YEA
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
NONROAD
ONROAD
AREA
POINT
St. Louis
Jefferson
St. Charles
Franklin
St. Louis City
Ste. Genevieve
Pike
Lincoln
St. Francois
Montgomery
Warren
Washington
Crawford
Gasconade
NH3 Total Emissions
Montgomery
Gasconade
Ste. Genevieve
Pike
Crawford
Washington
St. Francois
WARREN
LINCOLN
FRANKLIN
JEFFERSON
ST. CHARLES
ST. LOUIS CITY
ST. LOUIS

Figure 2.3-7 Current St Louis Area Emissions

1999 NEI DRAFT V.3 - 2001 MoEIS - 2001 TRI

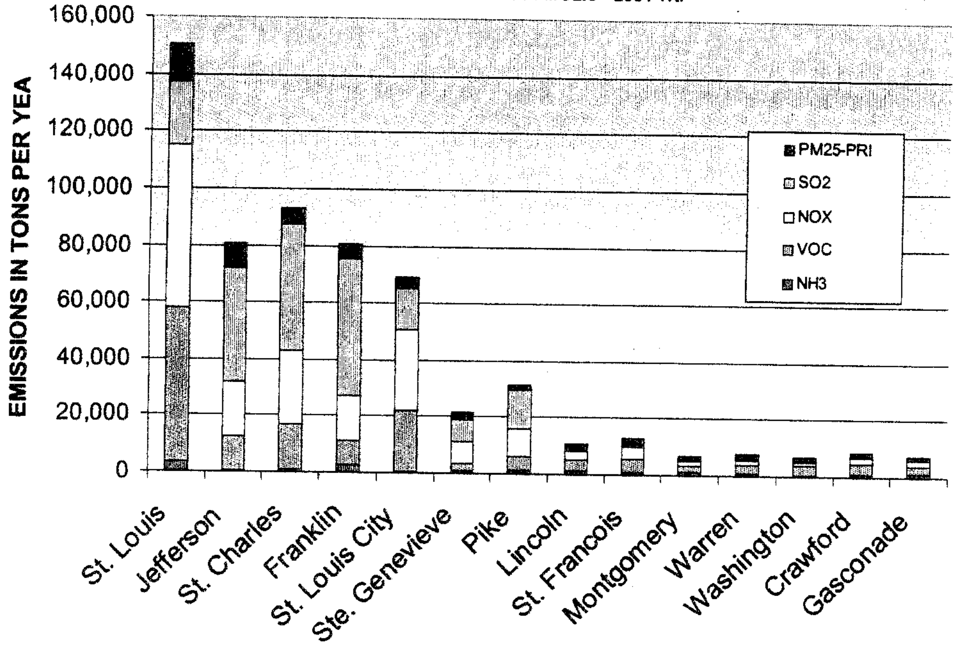
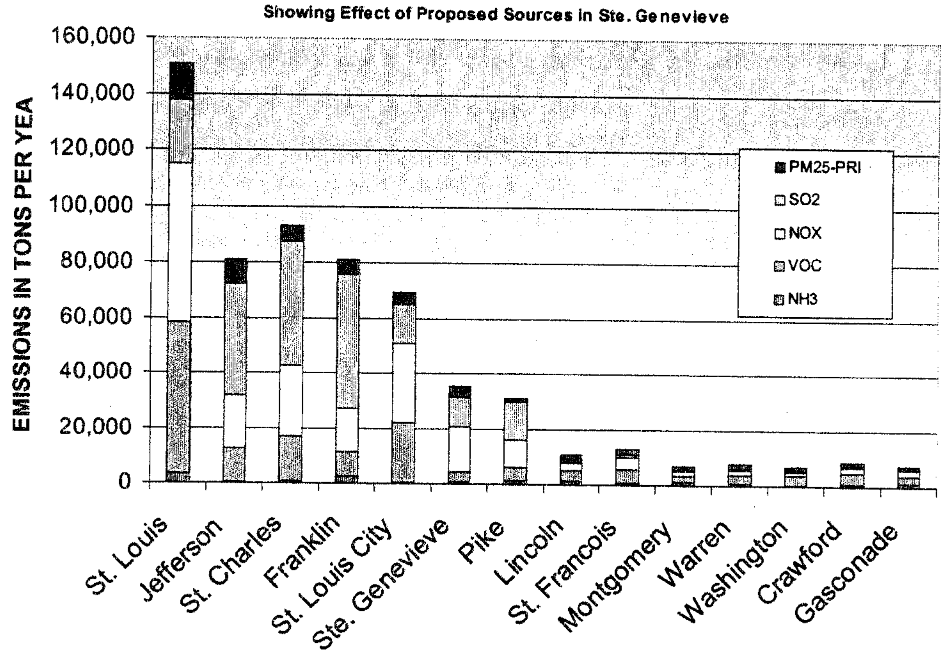


Figure 2.3-8. Projected St. Louis Area Emissions

Showing Effect of Proposed Sources in Ste. Genevieve



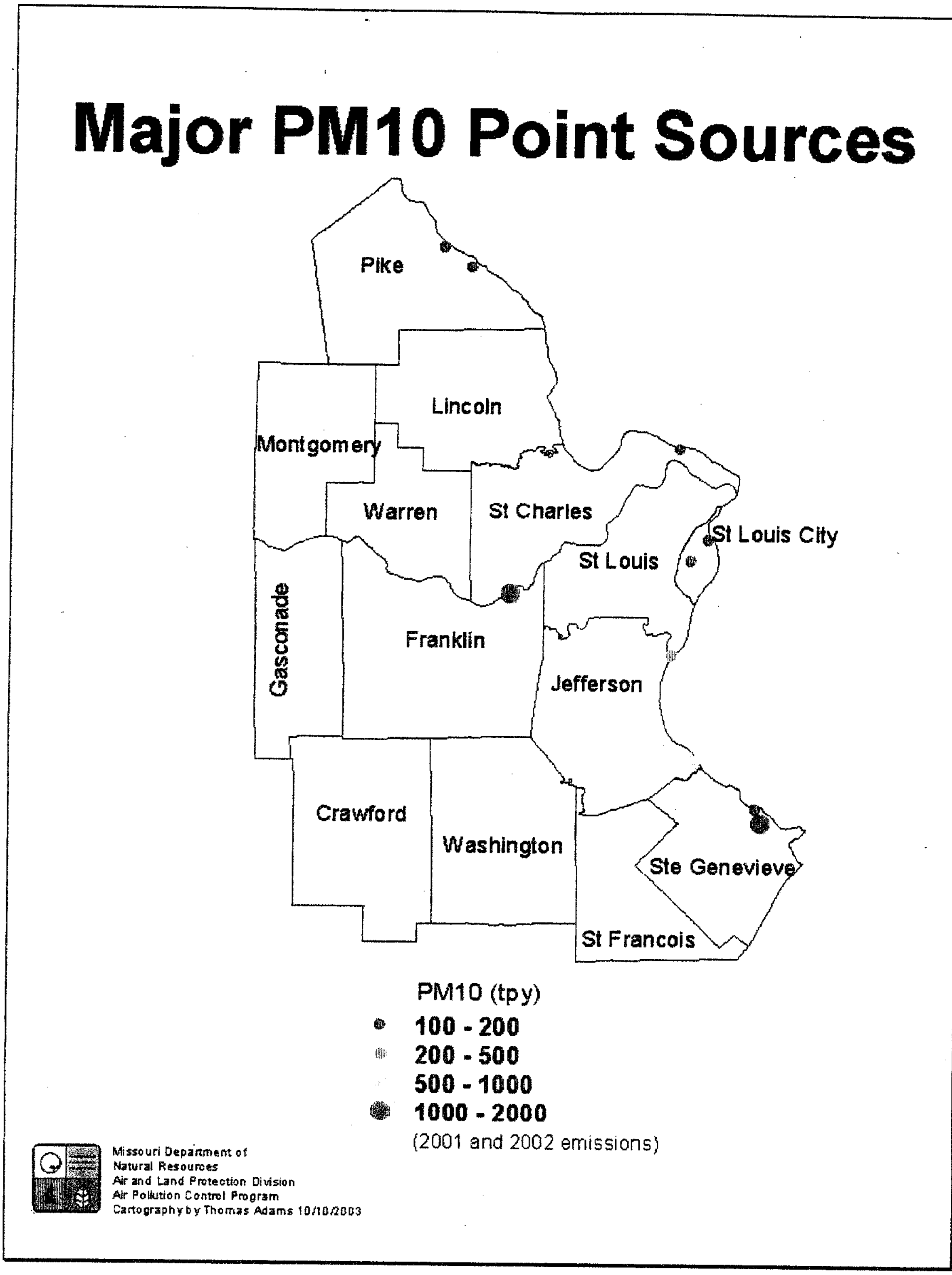


Figure 2.3-9. Locations of major point sources of PM_{10}.

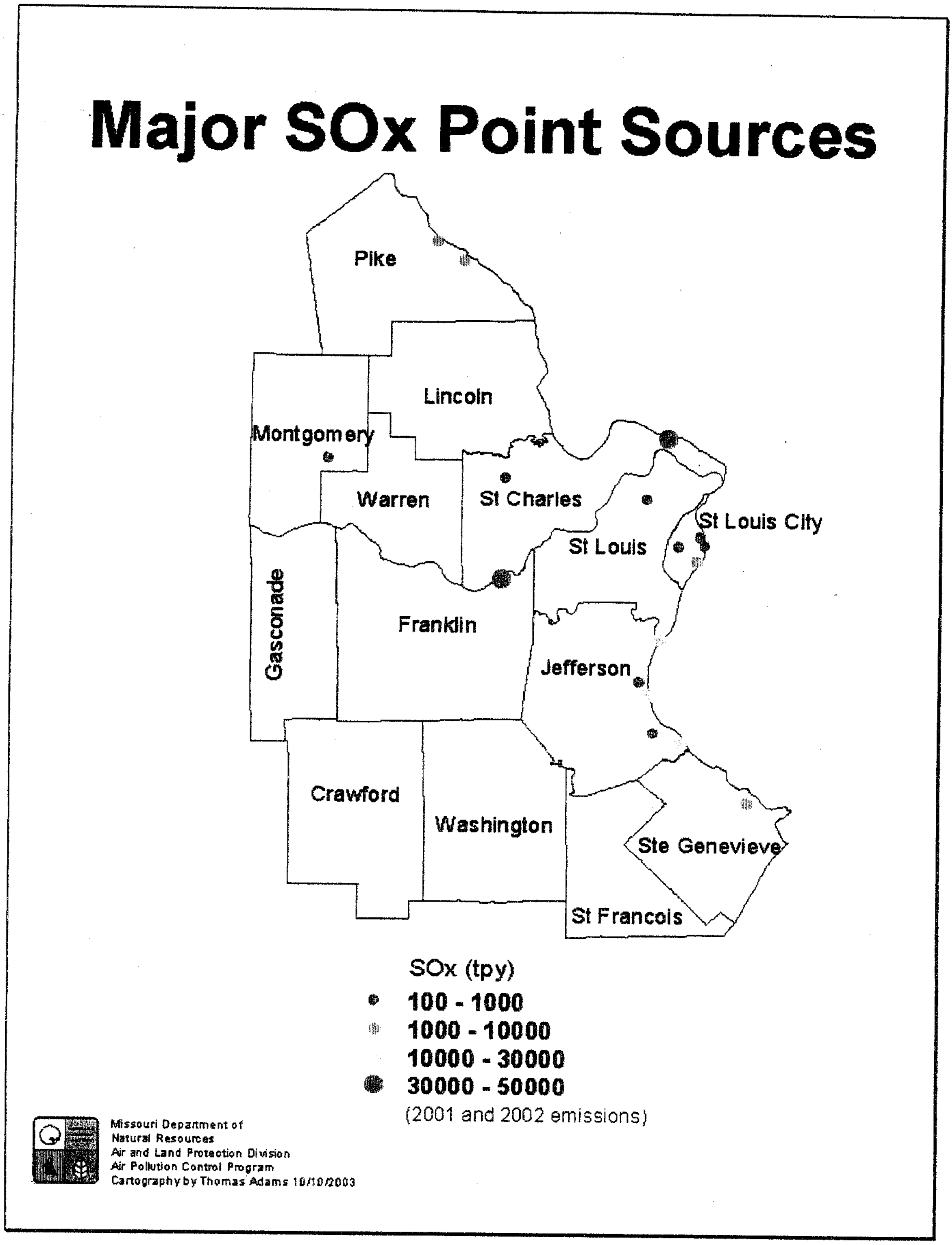


Figure 2.3-10. Locations of major point sources of SO_X.

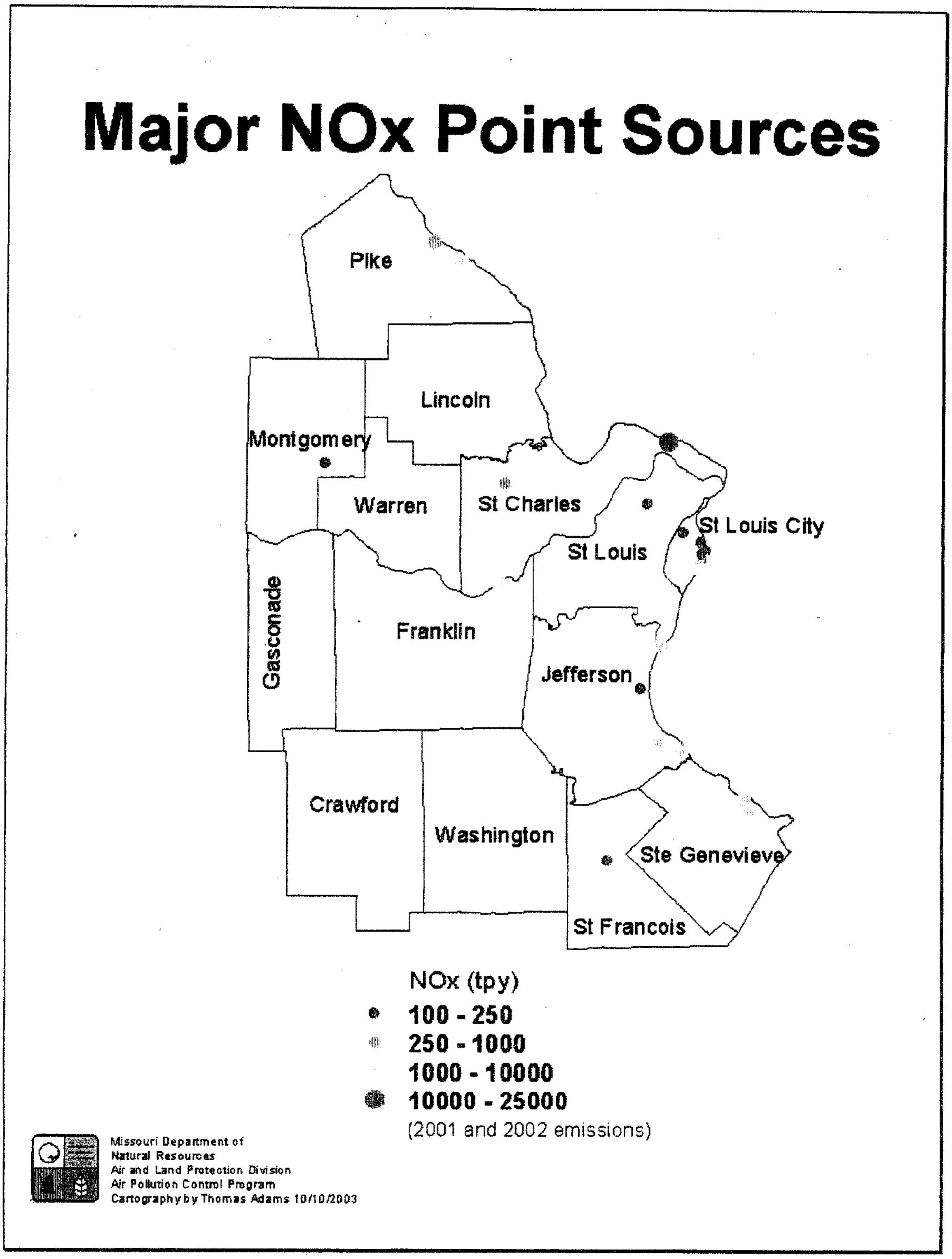


Figure 2.3-11. Locations of major point sources of NO_X.

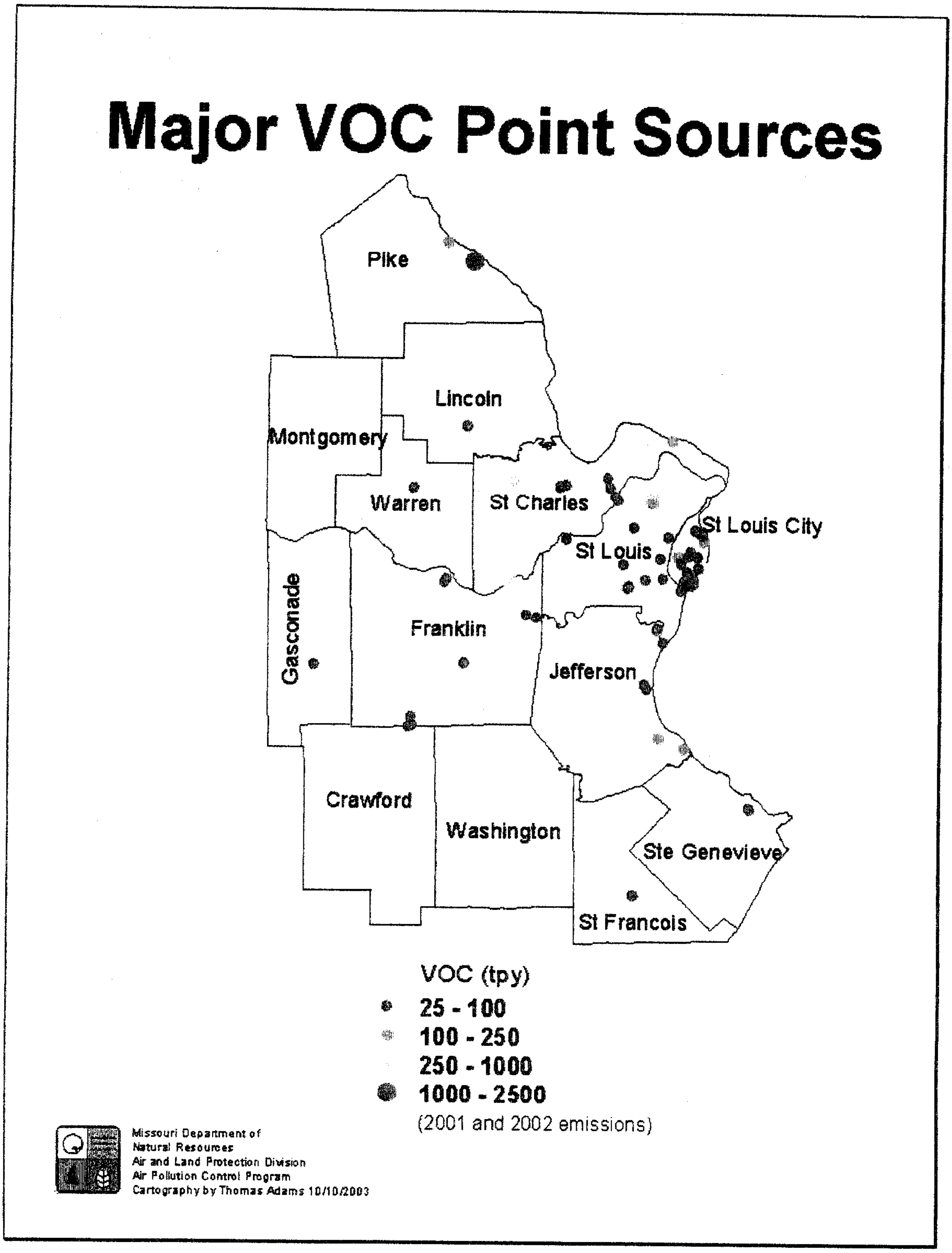


Figure 2.3-12. Locations of major point sources of VOC.

2.3.2 Population Density and Urbanization

Table 2.3-2 lists employment (year 2000) and population (years 1990 and 2000) data for the six Missouri counties in the St. Louis MSA, St. Louis City, the six Illinois counties in the St. Louis MSA, and seven additional Missouri counties bordering on the MSA. Six of the 12 MSA counties and the City of St. Louis each had a population (year 2000) greater than 70,000 people. With the exception of Monroe County, Illinois, these counties plus St. Louis City are identical to those in the 1-hour ozone maintenance area, and the Missouri area is identical to that recommended as constituting the 8-hour ozone nonattainment area. None of the other counties listed has a high population. Figure 2.3-13 shows population density (year 2000) in persons per square mile. This figure shows an urban population base that includes most of St. Louis City and County, northern Jefferson County, and a portion of St. Charles County. Pockets of higher population density are located in Franklin and St. Francois Counties. Figure 2.3-14 shows urban areas in the St. Louis region. This figure supports the same conclusions as the population density figure. Much of the urbanization has occurred in the area contiguous to St. Louis City with St. Charles County as a notable exception.

The employment data in Table 2.3-2 show high employment in the 1-hour ozone maintenance counties with respect to the MSA and other surrounding counties (98% of the MSA employment). St. Francois County is the only other county with employment larger than 1% of the MSA total (1.4%).

2.3.3 Expected Population Growth

As listed in Table 2.3-2, population growth above 15% occurred in the following counties between 1990 and 2000: Franklin, Jefferson, St. Charles, Lincoln, Warren, Crawford, and Monroe in Illinois. Additional population growth information, including growth projections, is presented in Table 2.3-3. The 2000-2020 population growth projection data show the same counties for growth above 15% as the 1990-2000 information. However, Lincoln and Warren counties still are expected to have less than 60,000 people in 2020. Of the larger counties, the highest growth rate for both periods is in St. Charles County, and St. Louis City has the largest population reduction for both periods.

2.3.4 Traffic and Commuting Patterns

Figure 2.3-15 illustrates the traffic patterns in the St. Louis area based on data provided by the Missouri Department of Transportation for 2001. These patterns suggest a typical pattern of high urban core traffic with the major interstate highways (70, 270, 44, and 55) contributing the majority of the remaining vehicle miles traveled (VMT). The interstate highways outside the core urban area contribute the majority of the VMT in those particular counties. St. Francois County is a notable exception to this statement, with no interstate highways and higher VMT than many of the other surrounding counties.

Additional connectivity information is included in Table 2.3-4, which is a matrix of residence and workplace by county for Missouri counties in the St. Louis area, based on 2000 census data. For example, the number of people that live in St. Louis County and work in Jefferson County can be determined (34,331). Several important pieces of information can be gained from review of this data:

- Over 90% of the employed people who live in the current 1-hour ozone maintenance area work in the maintenance area,

- The vast majority of employed people who live in the MSA work in the MSA,

- Lincoln, Warren, Jersey (IL), and Clinton (IL) counties have the highest percentage of people who work in the 1-hour ozone maintenance area, but the total number of employed residents is less than 20,000 per county,

- There is no strong linkage to the 1-hour ozone maintenance area from any of the non-MSA counties in Missouri.

Table 2.3-2. Population and Employment Data for the St. Louis Area

	2000 Employment	1990 Population	2000 Population	2000 Pop % of MSA	Pop Growth 1990-2000
MISSOURI					
ST. LOUIS	586,848	993,529	1,016,315	39.0%	2.3%
ST. LOUIS CITY	263,578	396,685	348,189	13.4%	-12.2%
ST. CHARLES	95,534	212,907	283,883	10.9%	33.3%
JEFFERSON	35,679	171,380	198,099	7.6%	15.6%
FRANKLIN	31,821	80,603	93,807	3.6%	16.4%
LINCOLN	6,922	28,892	38,944	1.5%	34.8%
WARREN	5,967	19,534	24,525	0.9%	25.6%
MISSOURI MSA	**1,026,349**	**1,903,530**	**2,003,762**	**77.0%**	**5.3%**
St. Francois	16,577	48,904	55,641	2.1%	13.8%
Washington	2,926	20,380	23,344	0.9%	14.5%
Crawford	5,152	19,173	22,804	0.9%	18.9%
Pike	3,810	15,969	18,351	0.7%	14.9%
Ste. Genevieve	5,284	16,037	17,842	0.7%	11.3%
Gasconade	4,698	14,006	15,342	0.6%	9.5%
Montgomery	2,850	11,355	12,136	0.5%	6.9%
ILLINOIS					
CLINTON	8,111	33,944	35,535	1.4%	4.7%
JERSEY	4,638	20,539	21,668	0.8%	5.5%
MADISON	85,279	249,238	258,941	9.9%	3.9%
MONROE	6,240	22,422	27,619	1.1%	23.2%
ST. CLAIR	75,291	262,852	256,082	9.8%	-2.6%
ILLINOIS MSA	**179,559**	**588,995**	**599,845**	**23.0%**	**1.8%**
MSA Total	**1,205,908**	**2,492,525**	**2,603,607**	**100.0%**	**4.5%**

COUNTY - Counties in the 1-Hour Ozone Maintenance Area

COUNTY - Counties in the MSA

County - Additional Counties

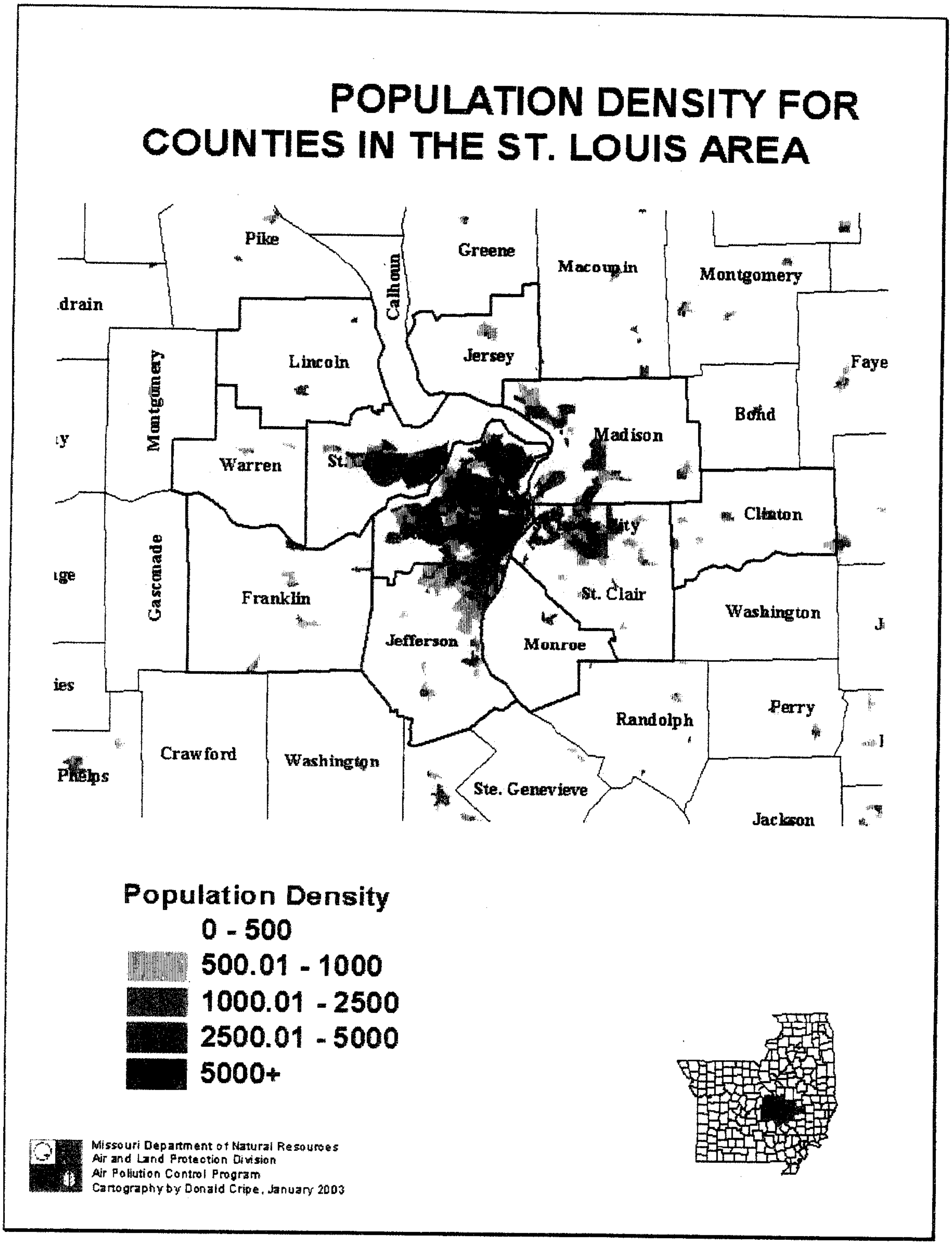


Figure 2.3-13. Population density (year 2000), persons per square mile, in the St. Louis area.

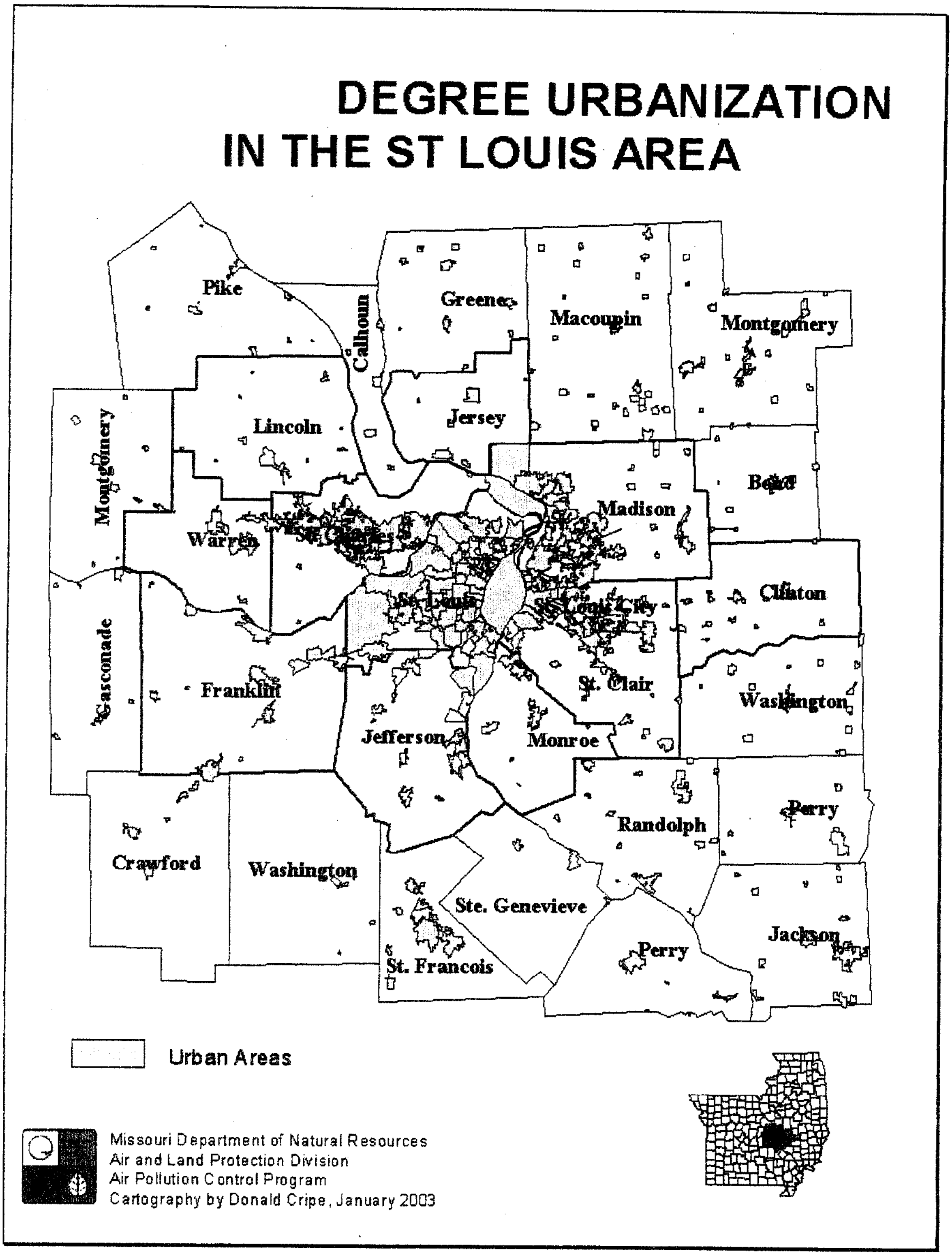


Figure 2.3-14. Urbanization in the St. Louis area.

Table 2.3-3. Population Projections by County for the St. Louis Area

	1990	1995	2000	2000 Actual	2005	2010	2015	2020	% Growth 2000-2020
MISSOURI									
ST. LOUIS	993,529	1,003,356	1,003,268	1,016,315	996,268	986,265	977,159	969,774	-3.3%
ST. LOUIS CITY	396,685	360,720	322,734	348,189	286,109	251,773	220,366	191,908	-40.5%
ST. CHARLES	212,907	246,339	281,816	283,883	315,618	348,587	381,032	411,984	46.2%
JEFFERSON	171,380	185,475	200,159	198,099	214,120	227,729	240,738	252,463	26.1%
FRANKLIN	80,603	87,296	94,339	93,807	100,937	107,200	113,067	118,279	25.4%
LINCOLN	28,892	32,743	37,183	38,944	41,650	46,235	50,838	55,260	48.6%
WARREN	19,534	22,354	25,219	24,525	28,043	30,864	33,656	36,273	43.8%
MISSOURI MSA	**1,903,530**	**1,938,283**	**1,964,718**	**2,003,762**	**1,982,745**	**1,998,653**	**2,016,856**	**2,035,941**	3.6%
St. Francois	48,904	53,092	56,673	55,641	59,831	62,753	65,324	67,530	19.2%
Washington	20,380	21,910	23,272	23,344	24,486	25,611	26,601	27,448	17.9%
Crawford	19,173	21,241	23,186	22,804	25,081	26,864	28,479	29,943	29.1%
Pike	15,969	16,145	16,760	18,351	16,809	16,829	16,783	16,677	-0.5%
Ste. Genevieve	16,037	16,597	17,317	17,842	17,977	18,591	19,153	19,610	13.2%
Gasconade	14,006	14,415	15,022	15,342	15,634	16,264	16,911	17,491	16.4%
Montgomery	11,355	11,606	11,933	12,136	12,269	12,592	12,876	13,095	9.7%
ILLINOIS									
CLINTON	33,944	35,309	36,086	35,535	36,574	37,147	38,010	39,032	8.2%
JERSEY	20,539	22,032	22,930	21,668	23,845	24,772	26,070	28,082	22.5%
MADISON	249,238	256,246	260,445	258,941	265,765	270,355	275,224	284,362	9.2%
MONROE	22,422	24,789	26,938	27,619	29,105	31,140	33,106	35,545	32.0%
ST. CLAIR	262,852	266,038	280,070	256,082	289,841	299,642	307,460	315,727	12.7%
ILLINOIS MSA	**588,995**	**604,414**	**626,469**	**599,845**	**645,130**	**663,056**	**679,870**	**702,748**	12.2%

Missouri information developed by the Office of Admininstration, Division of Budget and Planning, May 1999
Illinois information developed by the Census Data and Users Service, Illinois State University, 1998

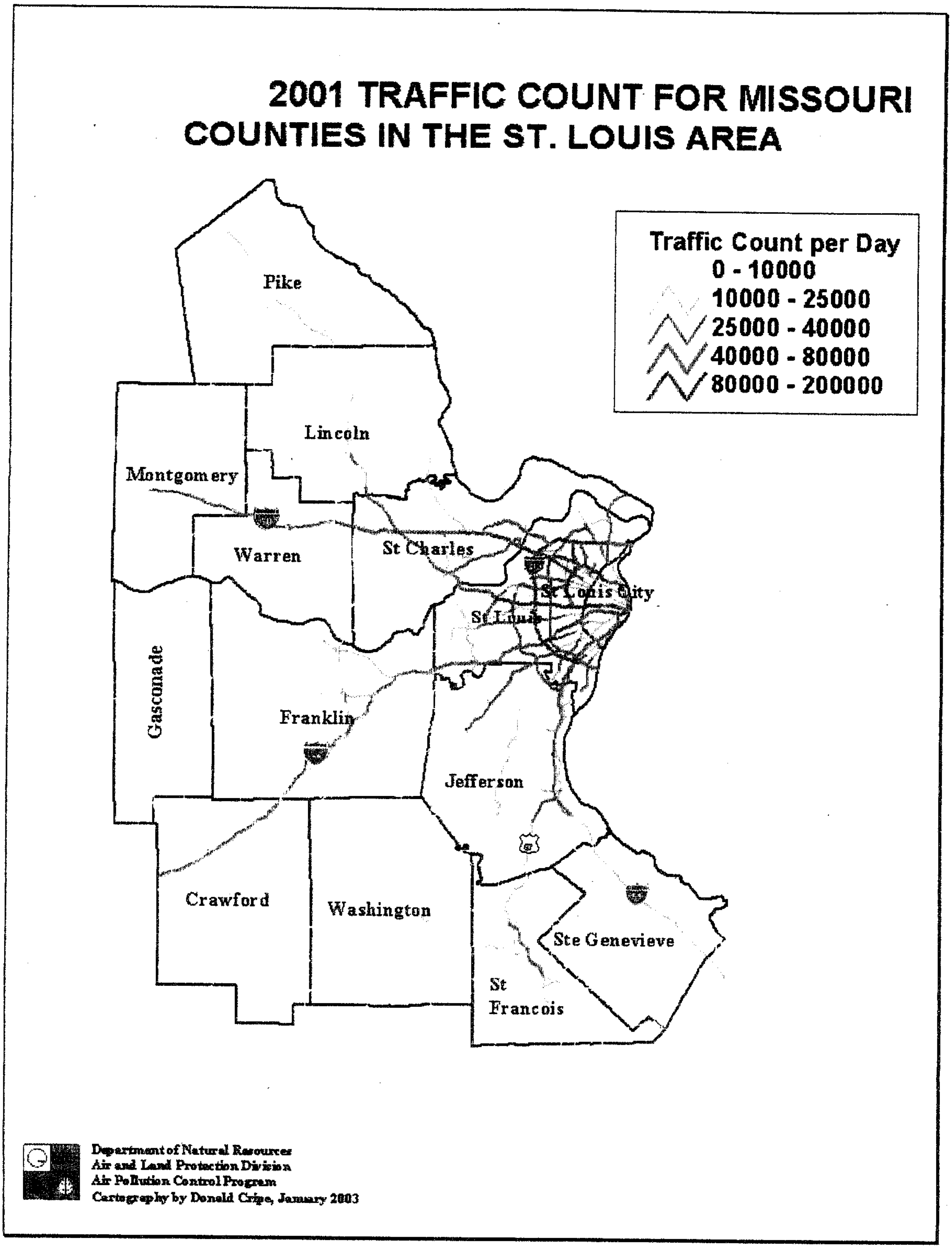


Figure 2.3-15. Traffic count for Missouri Counties in the St. Louis area.

Table 2.3-4. Place of Residence/Employment Matrix by County for the St. Louis Area											
Residence						Employment (Missouri)					
	Crawford	Franklin	Gasconade	Jefferson	Lincoln	Montgomery	Pike	St. Charles	St. Francois	St. Louis	St. L. City
MISSOURI											
ST. LOUIS	24	1,752	46	5,463	116	27	11	12,859	89	358,742	105,207
ST. LOUIS CITY	17	291	0	1,181	12	0	0	1,439	32	50,997	82,480
ST. CHARLES	7	555	15	380	729	38	85	70,058	6	62,353	10,930
JEFFERSON	3	1,013	5	34,331	35	4	0	1,291	410	42,181	15,947
FRANKLIN	451	27,161	750	780	15	11	0	766	0	11,842	2,253
LINCOLN	0	40	0	23	8,314	45	229	5,529	0	2,738	702
WARREN	13	879	24	18	185	204	2	2,967	6	1,972	311
MISSOURI MSA	515	31,691	840	42,176	9,406	329	327	94,909	543	530,825	217,830
St. Francois	7	79	0	1,496	0	0	1	81	15,798	1,473	896
Washington	94	573	0	799	11	0	0	27	1,235	869	418
Crawford	5,371	1,728	208	60	0	0	0	65	13	733	206
Pike	0	0	0	5	474	40	5,167	294	0	146	106
Ste. Genevieve	0	15	0	679	0	0	0	43	896	620	366
Gasconade	52	1,103	4,337	4	6	109	0	46	0	427	107
Montgomery	2	155	306	0	73	3,007	16	362	0	231	29
MISSOURI Total	6,041	35,344	5,691	45,219	9,970	3,485	5,511	95,827	18,485	535,324	219,958
ILLINOIS											
CLINTON	0	11	0	25	0	0	0	49	3	529	1,097
JERSEY	0	0	0	28	0	0	0	125	0	1,111	404
MADISON	0	136	8	288	11	0	9	1,051	0	16,780	14,499
MONROE	0	23	0	205	0	0	0	84	0	3,333	2,376
ST. CLAIR	0	130	0	304	3	0	0	640	13	12,582	18,251
ILLINOIS MSA	0	300	8	850	14	0	9	1,949	16	34,335	36,627
Total	6,041	35,644	5,699	46,069	9,984	3,485	5,520	97,776	18,501	569,659	256,585
Total Workforce	6,674	36,230	6,386	46,679	10,231	3,826	6,604	98,677	20,350	580,137	262,981

2.4 METEOROLOGY

2.4.1 Association of $PM_{2.5}$ with Meteorological Conditions

As discussed in Section 2.2, there is a widespread regional background of about 10-11 $\mu g/m^3$ of $PM_{2.5}$ and an additional 5-6 $\mu g/m^3$ of $PM_{2.5}$ in the St. Louis urban area. Therefore, some understanding of regional as well as local meteorology, along with the speciation results presented in Section 2.2, is useful in understanding regional and local contributions to the $PM_{2.5}$ concentration in the St. Louis area.

The air monitoring results presented in Sections 2.1 and 2.2, as well as a recent review of Midwestern $PM_{2.5}$ measurement results (Lake Michigan Air Directors Consortium, $PM_{2.5}$ in the Upper Midwest, June 2, 2003), do not show large seasonal differences in concentrations, but summer and winter concentrations are slightly higher than spring and fall. The higher summer concentrations occur in both urban and rural areas, suggesting widespread source contributions, whereas higher winter concentrations occur mainly in urban areas, suggesting a stronger influence of local sources during winter. This observation, in combination with the speciation results presented in Section 2.2, suggest that sulfate, which is higher in summertime, is largely from widespread regional sources, while organic and elemental carbon and nitrate, which are higher in fall and winter, may result from local sources.

A recent study of summertime $PM_{2.5}$ concentrations and meteorological conditions in midwestern cities, including St. Louis (Steven G. Brown, letter to Michael Koerber, Lake Michigan Air Directors Consortium re. $PM_{2.5}$ Forecasting – Synoptic Typing, September 18, 2003, Sonoma Technology, Inc.), makes the following observations:

- Generally, higher summertime $PM_{2.5}$ concentrations (above 30 $\mu g/m^3$) occur with southerly flow, calm winds, or the presence of a surface high or stationary front. Persistence in the 500 millibar meteorological regime appears to lead to increased $PM_{2.5}$ concentrations,

- Low summertime concentrations (generally below 20 $\mu g/m^3$) most often occur when a front passes through, when a surface low is present, or when there is northerly or westerly flow,

- Easterly flow can produce a wide range of concentrations,

- An upper-level ridge or flat flow generally produces higher summertime $PM_{2.5}$ concentrations (above 30 $\mu g/m^3$), while a trough or zonal flow produces lower concentrations (generally below 20 $\mu g/m^3$),

- Inversion height and strength do not appear to be as important in summer as in winter. In summer, inversions often dissipate in the morning. An exception is St. Louis,

where a strong or moderate inversion was present for nearly all days with $PM_{2.5}$ concentrations above 40 $\mu g/m^3$.

2.4.2 Wind Roses

Figure 2.4-1 shows a wind rose for wind measurements at the Lambert-St. Louis International Airport for the years 2000 to 2002. Each lobe on the wind rose represents wind from one of 16 compass points. The length of each lobe represents the percentage of time that the wind is from a particular direction. The various shadings show the percentage of time that wind from a particular direction is in a particular range of wind speed. The dominant feature of this wind rose is the high frequency of wind from the south. Other notable features are the frequency of wind from the west to northwest, and the relative lack of wind from the northeast.

Figures 2.4-2 to 5 show wind roses for the same location for the first, second, third, and fourth calendar quarters for the years 2000 to 2002. The first quarter wind rose shows the dominant southern wind but also a strong component from the west to northwest. The second quarter wind rose shows a very strong southern component. The third quarter wind rose shows a southern component that is not quite as strong and a strong eastern component. The fourth quarter wind rose is similar to the one for the first quarter, showing strong southern and west to northwest components.

2.4.3 Trajectory Analysis

A recent study of source apportionment and trajectory analysis of $PM_{2.5}$ speciation results for approximately the first year at the Blair St. site in St. Louis (Basil Coutant et al., Revised Draft Report on Source Apportionment of $PM_{2.5}$ Speciation Trends Data, Battelle Memorial Institute, prepared for US EPA, September 2002) included analysis of back trajectory modeling results generated using HYSPLIT (www.arl.noaa.gov/ready/hysplit4.html).

HYSPLIT generates back trajectories using an 80 kilometer grid of meteorological data and so does not have the spatial resolution to identify local point sources. However, source contribution function plots for worst sulfate days (plots on a map of the probability that a worst-day trajectory passes through a region) support the conclusion that sulfate originates in regions with a high density of coal burning including the Ohio River Valley and adjacent states. In addition, trajectories for high sulfate days typically show clockwise curvature, indicating flow around a high pressure area, with corresponding downward vertical flow that would tend to trap emissions near the ground. Trajectories for worst nitrate days generally show air flow from the north, likely indicative of colder days conducive to nitrate condensation rather than specific source locations. These results are consistent with those discussed above and with speciation results presented in Section 2.2, all suggesting that sulfate results from widespread sources, while nitrate may result from more localized sources.

The Missouri Department of Natural Resources Air Pollution Control Program has also conducted back trajectory modeling using HYSPLIT for all days with $PM_{2.5}$ concentrations greater than 25 $\mu g/m^3$ at one or more locations in the St. Louis area, including Illinois sites, for 2000 and 2001, as well as for selected days with high concentrations of one or more of the major species. Some of the results of this analysis are presented in Appendix A.

Seventy-two hour back trajectories for days with high $PM_{2.5}$ (and high sulfate) in summer generally either show clockwise curvature (around a high pressure area) and are from an easterly direction (the Ohio River Valley), consistent with the source contribution results described above, or show flow from a westerly direction, originating in the area of Texas. Both of these types of trajectories enter the St. Louis area from the south, consistent with wind rose results showing a dominant southerly flow.

Trajectories for days with high $PM_{2.5}$ (and high ammonium and/or nitrate) in winter or spring are generally from the north, consistent with cold weather conducive to nitrate condensation. Again, this result is consistent with those described above.

Trajectories for days with high organic and/or elemental carbon days in fall do not show a consistent pattern, suggesting that organic and/or elemental carbon may originate from local sources beyond the resolution of the 80 kilometer grid of meteorological data used to generate the trajectories.

In addition, US EPA Region 7 has recently conducted systematic trajectory cluster analysis using sulfate, nitrate, and organic carbon $PM_{2.5}$ speciation measurement results from the Blair St. site in St. Louis. This analysis generates back trajectories using HYSPLIT and then groups trajectories into clusters. Trajectory clusters are generated by comparing the four-dimensional (latitude, longitude, pressure, and time) data defining each air parcel trajectory with the data for every other trajectory. Trajectories are then grouped into clusters by their proximity to one another using a chosen radius of proximity. Once the first cluster is generated in this way, the remaining trajectories are analyzed in the same way and the process repeated. Remaining trajectories are then assigned to clusters if they are within twice the radius of proximity of a cluster.

The analysis resulted in eight trajectory clusters. In general, results were consistent with those described above. The average trajectories for clusters with higher than average sulfate showed clockwise curvature and paths either along the Ohio River Valley or upper Missippi River Valley. The average trajectories for clusters with higher than average nitrate showed paths from the north or northwest. The average trajectories for clusters with higher than average organic carbon showed either flow through the Ohio River Valley or flow from the west, with minimal deviation from the average, suggesting that local sources may be relatively more important for organics.

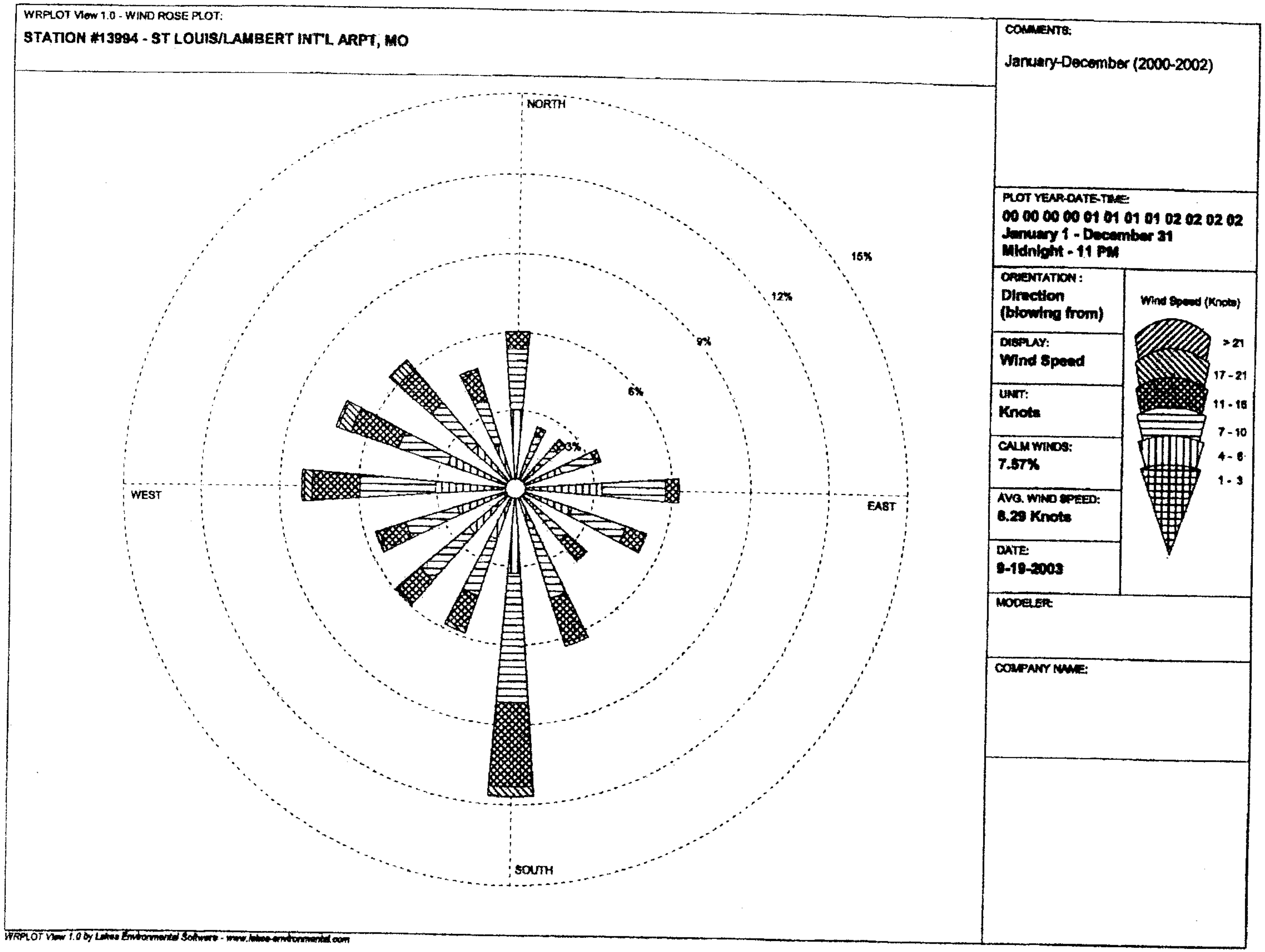


Figure 2.4-1. Wind rose for St. Louis, 2000-2002.

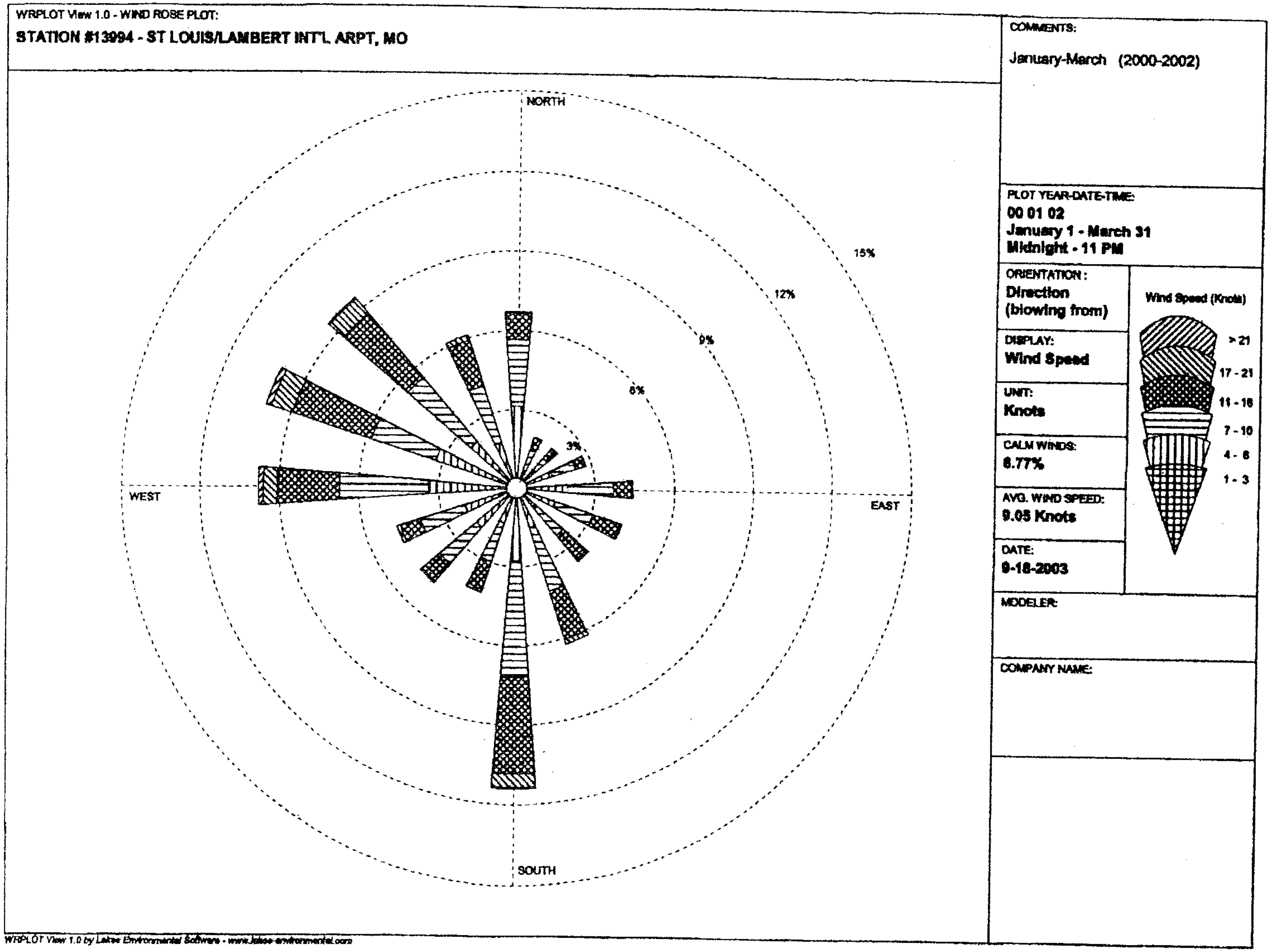


Figure 2.4-2 Wind rose for St. Louis, first quarter 2000-2002.

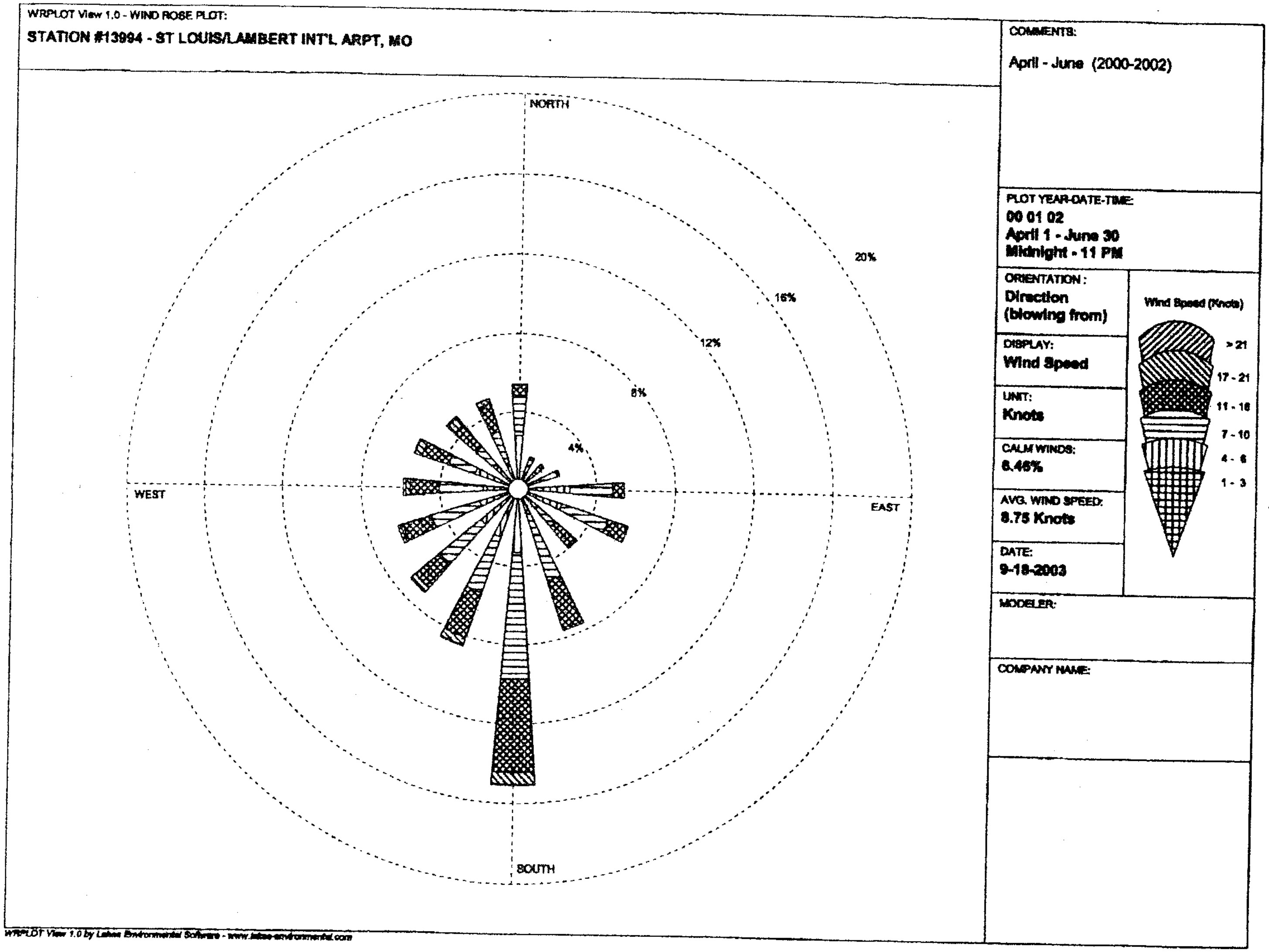


Figure 2.4-3. Wind rose for St. Louis, second quarter 2000-2002.

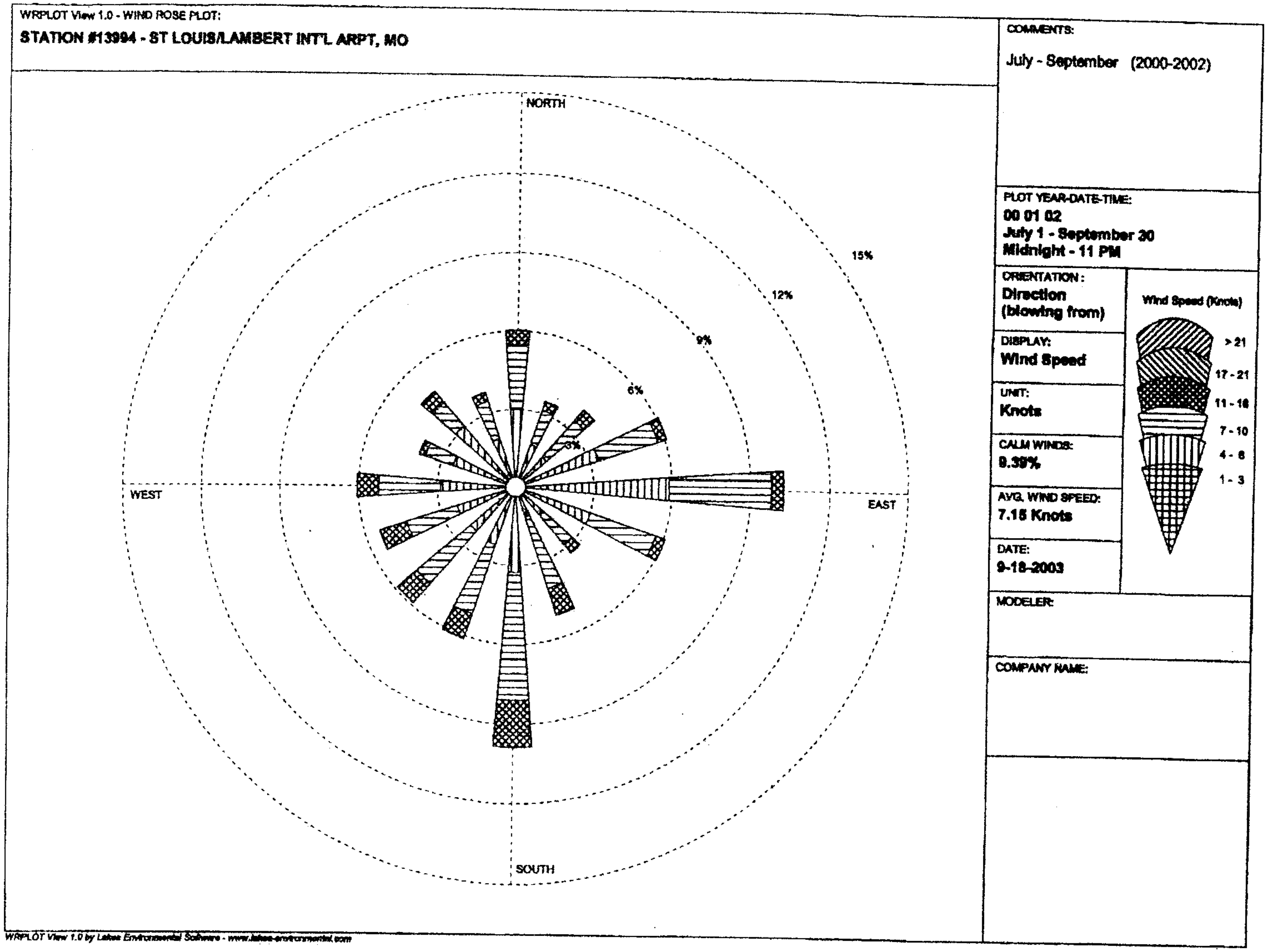


Figure 2.4-4. Wind rose for St. Louis, third quarter 2000-2002.

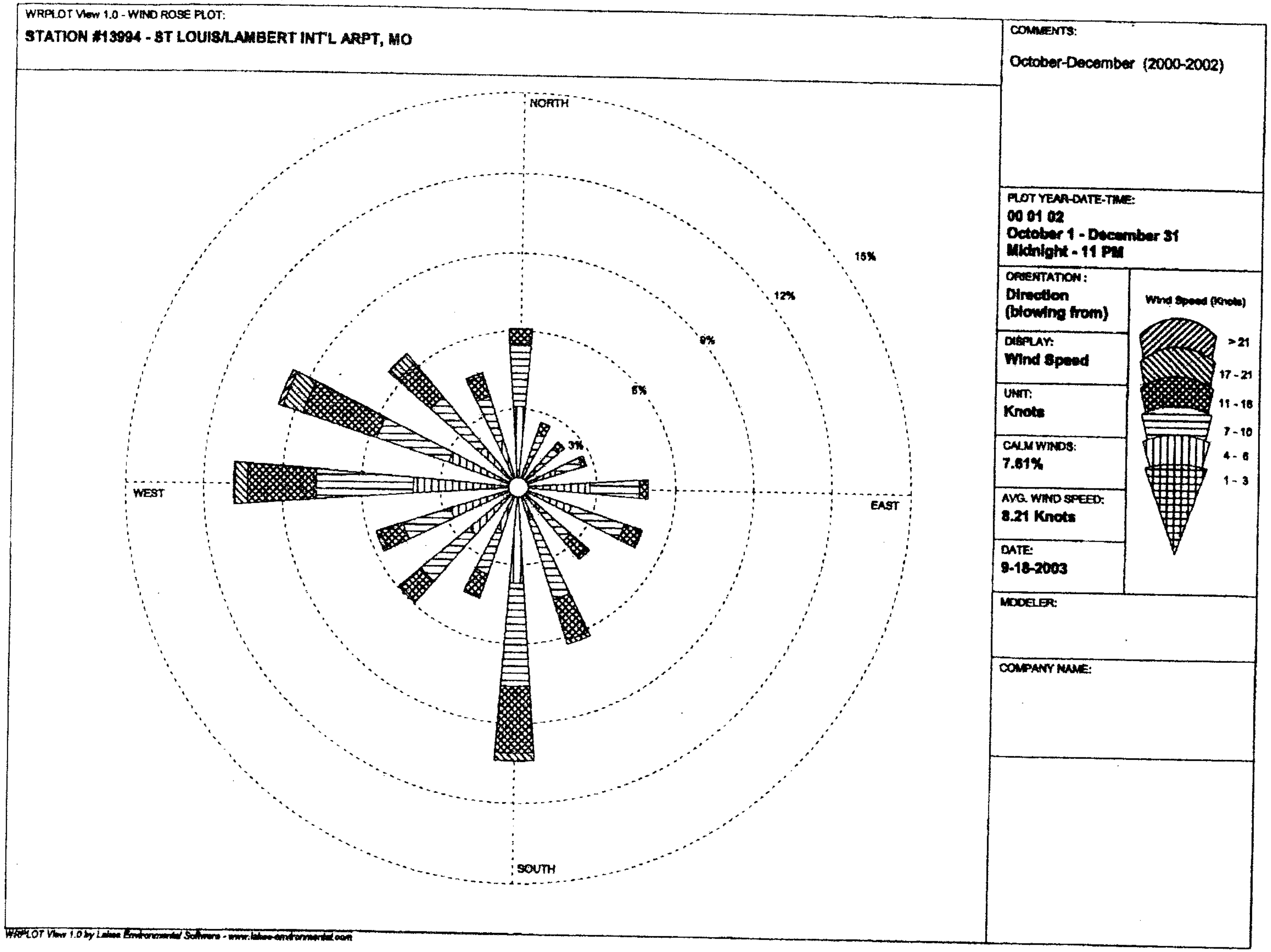


Figure 2.4-5. Wind rose for St. Louis, fourth quarter 2000-2002.

2.5 GEOGRAPHY AND TOPOGRAPHY

There are no geographic or topographic features in the St. Louis area that are significant in the context of defining the $PM_{2.5}$ nonattainment area.

2.6 DISCUSSION OF FACTORS AND CONCLUSIONS

The $PM_{2.5}$ air monitoring data presented in Section 2.1 show nonattainment of the annual standard for the years 2000-2002 for the Blair St. site and potentially for the South Broadway site in the City of St. Louis (South Broadway has less than three full years of data). The remaining St. Louis City site (Margaretta) and Missouri monitoring sites in counties immediately surrounding the City of St. Louis (St. Louis, St. Charles, and Jefferson Counties) show average concentrations approaching, but not exceeding, the standard.

$PM_{2.5}$ speciation results in the St. Louis area indicate that the species contributing most of the $PM_{2.5}$ mass are ammonium sulfate, ammonium nitrate, organic compounds, and elemental carbon. The sulfate contribution is highest in the summer, and the nitrate contribution is highest in the winter.

Comparison of $PM_{2.5}$ mass and speciation measurement results for the St. Louis area to those for rural areas shows an urban excess of 5 to 6 $\mu g/m^3$, which (on an annual basis) is predominantly carbonaceous material (organic compounds and elemental carbon) and nitrate. Differences in these species (carbonaceous material and nitrate) also appear between urban core and suburban sites in the St. Louis area. Sulfate, on the other hand, appears to be more regional.

Emission inventory data and population data are summarized in Table 2.6-1 for St. Louis area counties in Missouri and Illinois. Table 2.6-1 shows emissions of various pollutants and 2000 population as percentages of totals for the St. Louis MSA. St. Louis City and the four adjoining counties highlighted at the top of the table show both higher emissions and higher population as compared to the surrounding counties listed below. Traffic density is highest in the core urban area and on the approaching interstate highways. Information on residence and workplace shows that most of the people that work in St. Louis City and the four adjoining counties live within the same area.

Meteorological analysis results complement the results of speciation measurements. High $PM_{2.5}$ mass and sulfate days in summer appear to result from air flow either from the Ohio River Valley area, which has numerous large sulfur oxide sources, or from the west. Both types of trajectories enter the St. Louis area from the south. High nitrate days in winter appear to result from air flow from the north, which is likely more of an indicator of cold weather enhancing nitrate condensation than of source direction. High carbonaceous material days, typically in fall, do not show a consistent trajectory pattern, possibly because the sources are relatively local.

The air quality data show nonattainment of the NAAQS in St. Louis City and concentrations approaching the standard in nearby counties. The emission and population data show a fairly clear distinction between levels in the counties highlighted in Table 2.6-1 and the other Missouri counties. Therefore, the recommended nonattainment area includes St. Louis City and St. Louis, St. Charles, Jefferson, and Franklin Counties, all of which are in the St. Louis MSA. As shown in Table 2.6-1, these counties account for from 84.2 to 99.7% of the emissions (by pollutant) in the Missouri portion of the MSA.

Lincoln and Warren Counties are in the MSA, but have both low emissions and low population as compared to the other counties. Therefore, these two counties are not recommended for inclusion in the nonattainment area.

St. Francois, Washington, Crawford, Gasconade, and Montgomery Counties are outside the MSA and have both low emissions and low population and are, therefore, not recommended for inclusion in the nonattainment area.

Pike County has somewhat higher NO_x and SO_x emissions than some of the other counties because of a small number of large point sources, but the levels are lower than those of the counties recommended for inclusion in the nonattainment area, and the population is relatively low. Also, since Pike County is to the north of the St. Louis area, and the higher $PM_{2.5}$ and sulfate days in the summer generally occur when winds are from the south, it is not likely that SO_x emissions from Pike County contribute significantly to summertime $PM_{2.5}$ in St. Louis. Given the distance of these sources from any large urbanized area, their impact would seem to be significant only when considered in a regional transport context.

Ste. Genevieve County also has slightly higher NO_x and SO_x emissions than some of the other counties because of a small number of large point sources, but, like Pike County, the levels are lower than those of the counties recommended for inclusion in the nonattainment area, and the population is relatively low. The air monitor in Ste. Genevieve County shows attainment of the NAAQS (see Section 3.1). As discussed in Section 2.3.1, permit applications have been received for sources, which, if constructed, would increase emissions, primarily of NO_x, in Ste. Genevieve County. NO_x emissions would increase to approximately the level of Franklin County. However, other emissions would remain lower than those of counties in the recommended nonattainment area. Also, Ste. Genevieve County is south of the St. Louis area, and the higher $PM_{2.5}$ and nitrate days in the summer generally occur when winds are from the north, so it is not likely that NO_x emissions from Ste. Genevieve County would contribute significantly to wintertime $PM_{2.5}$ in St. Louis. As with Pike County, these sources would seem to be significant only in the context of regional transport.

For the reasons just presented, Pike and Ste. Genevieve Counties are not recommended for inclusion in the nonattainment area.

Table 2.6-1. Summary of St. Louis Area Designation Factors	VOC	NOx	SOx	PM10	PM2.5	NH3	2000 Population	2000 Pop. Density
	% of MSA	% of MSA	% of MSA	% of MSA	% of MSA	% of MSA	% of MSA	**
MISSOURI:								
ST. LOUIS (meets standard*)	34.4%	27.0%	9.3%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ST. LOUIS CITY (exceeds standard*)	13.5%	13.7%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ST. CHARLES (meets standard*)	9.9%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JEFFERSON (meets standard*)	7.6%	9.1%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FRANKLIN	5.6%	7.4%	20.0%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LINCOLN	2.3%	1.4%	0.1%	6.0%	4.3%	6.4%	1.5%	1.0
WARREN	1.9%	0.9%	0.1%	4.1%	3.0%	3.7%	0.9%	0.9
St. Francois	3.0%	2.1%	0.3%	5.5%	4.1%	3.7%	2.1%	1.9
Washington	2.1%	0.6%	0.1%	3.6%	2.5%	2.9%	0.9%	0.5
Crawford	2.5%	1.1%	0.0%	3.4%	2.5%	3.6%	0.9%	0.9
Pike	3.0%	4.7%	5.6%	3.0%	2.7%	6.2%	0.7%	0.4
Ste. Genevieve (meets standard*)	1.6%	3.5%	3.3%	3.6%	4.4%	4.7%	0.7%	0.6
Ste. Genevieve (growth)	2.0%	7.7%	4.5%	4.1%	6.3%	4.7%	----	----
Gasconade	1.5%	1.0%	0.1%	2.5%	1.8%	6.4%	0.6%	0.5
Montgomery	1.2%	0.9%	0.1%	3.5%	2.5%	6.4%	0.5%	0.4
ILLINOIS:								
CLINTON	1.5%	1.8%	0.2%	3.9%	3.1%	11.6%	1.4%	1.1
JERSEY	0.8%	0.9%	0.1%	2.2%	1.8%	2.4%	0.8%	0.9
MADISON (exceeds standard*)	12.7%	18.4%	27.4%	8.9%	13.3%	11.6%	7.9%	5.5
MONROE	0.9%	1.2%	0.1%	2.5%	2.1%	4.4%	1.1%	1.0
ST. CLAIR (exceeds standard*)	9.0%	5.8%	1.7%	6.9%	7.5%	6.1%	9.8%	5.9
Sum of highlighted counties compared to total MSA	70.9%	69.6%	70.2%	65.5%	64.8%	53.8%	76.7%	----
Sum of highlighted counties compared to MO portion of MSA	94.5%	96.8%	99.7%	86.6%	89.9%	84.2%	99.7%	----

*meets or exceeds standard means that annual standard is met at all monitoring sites or exceeded at one or more.

Counties without monitors do not have this note.

**population density metric is population/total county acreage * 10

3.0 REMAINDER OF MISSOURI

3.1 $PM_{2.5}$ AIR MONITORING RESULTS

There are eleven Federal Reference Method (FRM) $PM_{2.5}$ monitoring sites in the Kansas City area, six in Missouri and five in Kansas, and nine others in Outstate Missouri (the remainder of the State outside the St. Louis and Kansas City areas).

Annual Average

In contrast to St. Louis, concentrations measured at the sites in the Kansas City area are nearer the 3-year average of background sites than to the NAAQS standard. There is no reason to expect that any sites in the Kansas City area will be in exceedance of the annual standard. The maximum concentration in the Kansas City area has been at the Locust site in downtown Kansas City. The $PM_{2.5}$ monitors at this site were moved in February 2003 to the nearby Troost site, because it was not possible to install the continuous $PM_{2.5}$ sampler at the existing site. The continuous monitor must be collocated with a FRM sampler for at least one year. The Troost site is very near the Locust site and has most of the same source influences.

Outstate sites vary in concentration from low at the background sites to fairly high at Ste. Genevieve. Ste. Genevieve is on the Missouri River and likely influenced by the same regional impacts that affect St. Louis, in addition to local sources. Concentrations at the other sites in metropolitan areas, like Springfield and St. Joseph, are closer to the background levels than to the standard. Concentrations at sites near specific sources, such as charcoal kilns or quarries, are slightly higher, but less than the standard. There is no reason to expect an exceedance of the annual standard at any Outstate site.

24-hour Average

Previous to the July 4, 2002 episode mentioned in section 2.1, there was only one site in the State that had 24-hour exceedances. This site is located near a charcoal kiln in Belle, Missouri that did not have complete emission controls. The site began operation in May of 2001 and recorded two values over the standard. Controls were installed in 2002, and subsequent values have not reached these high levels.

Table 3.1-1. Annual $PM_{2.5}$ Total Mass for 2000-2002

24-hr Std = 65 $\mu g/m^3$, 98th percentile **Annual Mean Std = 15.0 $\mu g/m^3$**

	98th percentile				Annual Mean			
Kansas City, MO	**2000**	**2001**	**2002**	**00-02**	**2000**	**2001**	**2002**	**00 - 02**
Liberty	23.8	28.0	30.3	**27.4**	11.2	12.3	12.3	**11.9**
North Kansas City	29.2	29.0	32.8	**30.3**	13.2	13.1	12.7	**13.0**
Sugar Creek	28.1	28.0	32.3	**29.5**	12.7	12.6	12.4	**12.6**
Locust	30.2	30.2	34.0	**31.5**	13.4	14.2	14.0	**13.9**
Main-Plaza	25.0	30.0	30.1	**28.4**	11.3	13.0	13.3	**12.5**
RG- South	24.7	26.9	26.0	**25.9**	10.9	11.4	11.7	**11.3**
Kansas City, KS								
JFK	28.0	30.5	25.3	**27.9**	13.4	13.6	13.3	**13.4**
Highland	26.2	24.6	30.8	**27.2**	11.0	11.5	12.1	**11.5**
Justice Center	25.2	27.3	30.0	**27.5**	11.4	12.2	12.3	**12.0**
Oxford	25.8	26.1	28.0	**26.6**	11.2	11.8	11.9	**11.6**
Black Bob	25.4	25.4	25.5	**25.4**	11.1	11.9	11.9	**11.6**
Outstate								
El Dorado Springs	27.3	24.6	28.9	**26.9**	11.7	11.6	11.8	**11.7**
Mark Twain St. Pk.	29.5	32.6	29.0	**30.4**	10.9	11.2	11.4	**11.2**
Ste. Genevieve	32.7	31.0	34.2	**32.6**	15.1	13.7	13.7	**14.2**
SMSU	26.7	28.5	27.8	**27.7**	12.3	12.2	12.7	**12.4**
St. Joseph Museum	26.8	29.0	30.9	**28.9**	11.9	12.9	13.0	**12.6**
Carthage	29.5	28.7	31.5	**29.9**	13.5	14.5	13.9	**14.0**
Belle	-	95.1	26.4			**Middle scale site**		
Columbia	-	-	29.3		-	-	12.4	
Mercer	-	-	24.8		-	-	11.7	

* - less than four full quarters
** - less than three full years

3.2 CONCLUSIONS

The $PM_{2.5}$ air monitoring data presented in Section 3.2 support a recommendation that all counties in Missouri, except for those in the St. Louis area that are discussed in Section 2.0, be designated as in attainment of the $PM_{2.5}$ NAAQS.

APPENDIX A. TRAJECTORY ANALYSIS

This appendix presents the results (with some discussion) of back trajectory modeling for some days with high values of one or more major species at St. Louis $PM_{2.5}$ sites. It also includes figures showing trajectories for days with $PM_{2.5}$ concentrations greater than 25 $\mu g/m^3$ at any St. Louis area site for the years 2000 and 2001.

Back trajectory modeling was conducted using HYSPLIT for some individual days with high values of one or more major species at the St. Louis sites. Specifically, the six highest days at Blair St. and the three highest days at Grant School were identified for the period from the beginning of operation through June 30, 2002 for the following species: mass, sulfate, nitrate, ammonium, organic carbon, and elemental carbon. From this set, 13 days were selected that showed more than one of the higher values. Figures A-1 through A-13 show 72-hour back trajectories for each of these days ending at 4 PM Central Standard time (22 UTC). Trajectories ending at 8 AM were also generated, with very similar results to the afternoon trajectories, but are not presented here. All trajectories used Blair St. as an end point because, with the 80 kilometer grid for meteorological data, results for Grant School would be nearly identical.

Figures A-1 through A-4 show trajectories for high mass and/or sulfate days in summer. The trajectories generally show clockwise curvature (around a high pressure area) and are generally from an easterly direction.

Figures A-5 through A-10 show trajectories for high mass and/or ammonium and/or nitrate days in winter and spring. The trajectories are generally from the north, consistent with cold weather conducive to nitrate condensation.

Figures A-11 through A-13 show trajectories for high organic and/or elemental carbon days in fall. The trajectories do not show a consistent pattern, suggesting that organic and/or elemental carbon may originate from local sources beyond the resolution of the 80 kilometer grid of meteorological data used to generate the trajectories.

In addition to the trajectories described above, back trajectories have been generated for all days in 2000 and 2001 with $PM_{2.5}$ concentrations greater than 25 $\mu g/m^3$ at any St. Louis area site, as listed in Table A-1. Trajectories are shown in the figures following the table. In the figures showing multiple trajectories, the red trajectory ends at 10 meters above ground level, and the blue trajectory ends at 1000 meters above ground level. Results are similar to those just described. Trajectories for days with high $PM_{2.5}$ (and high sulfate) in summer generally either show clockwise curvature (around a high pressure area) and are from an easterly direction (the Ohio River Valley), consistent with the source contribution results described above, or show flow from a westerly direction, originating in the area of Texas. Both of these types of trajectories enter the St. Louis area from the south. Trajectories for days with high $PM_{2.5}$ (and high ammonium and/or nitrate) in winter or spring are generally from the north, consistent with cold weather conducive to nitrate condensation.

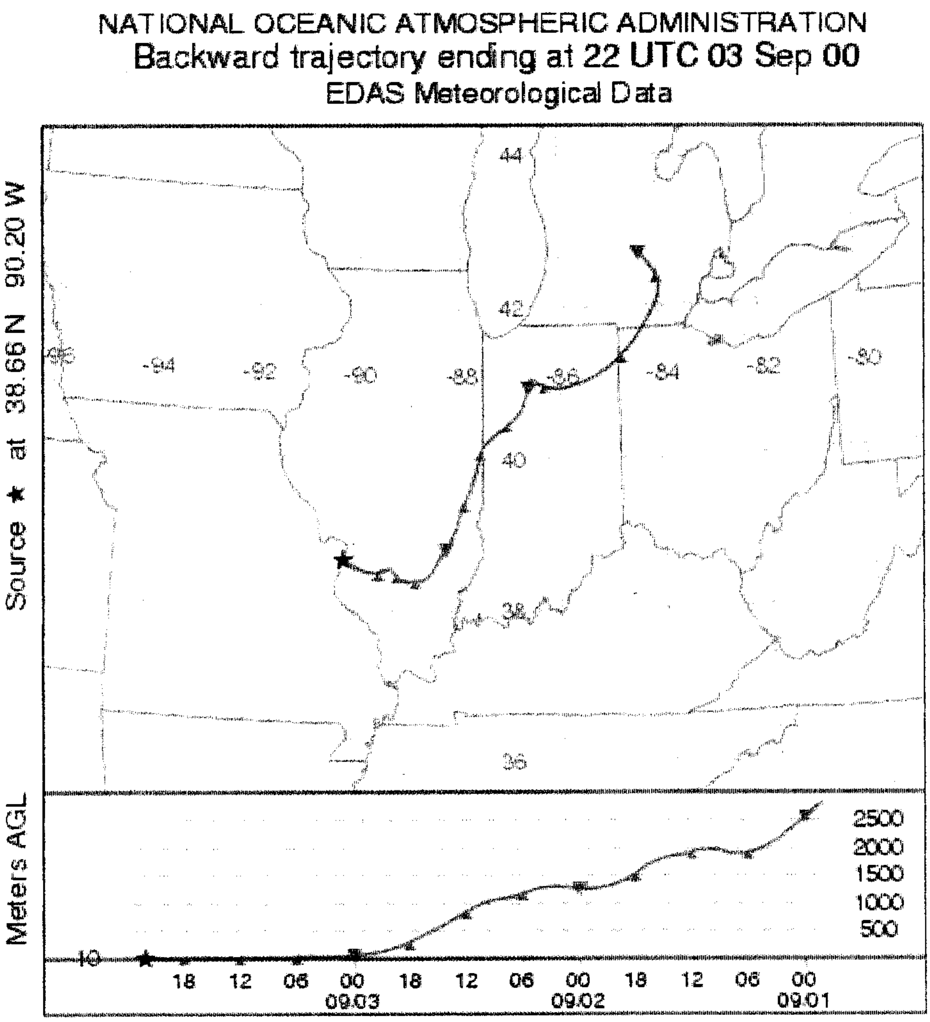


Figure A-1. Blair St. mass = 35.55 μg/m^3, sulfate = 12.30 μg/m^3, and ammonium = 5.90 μg/m^3.

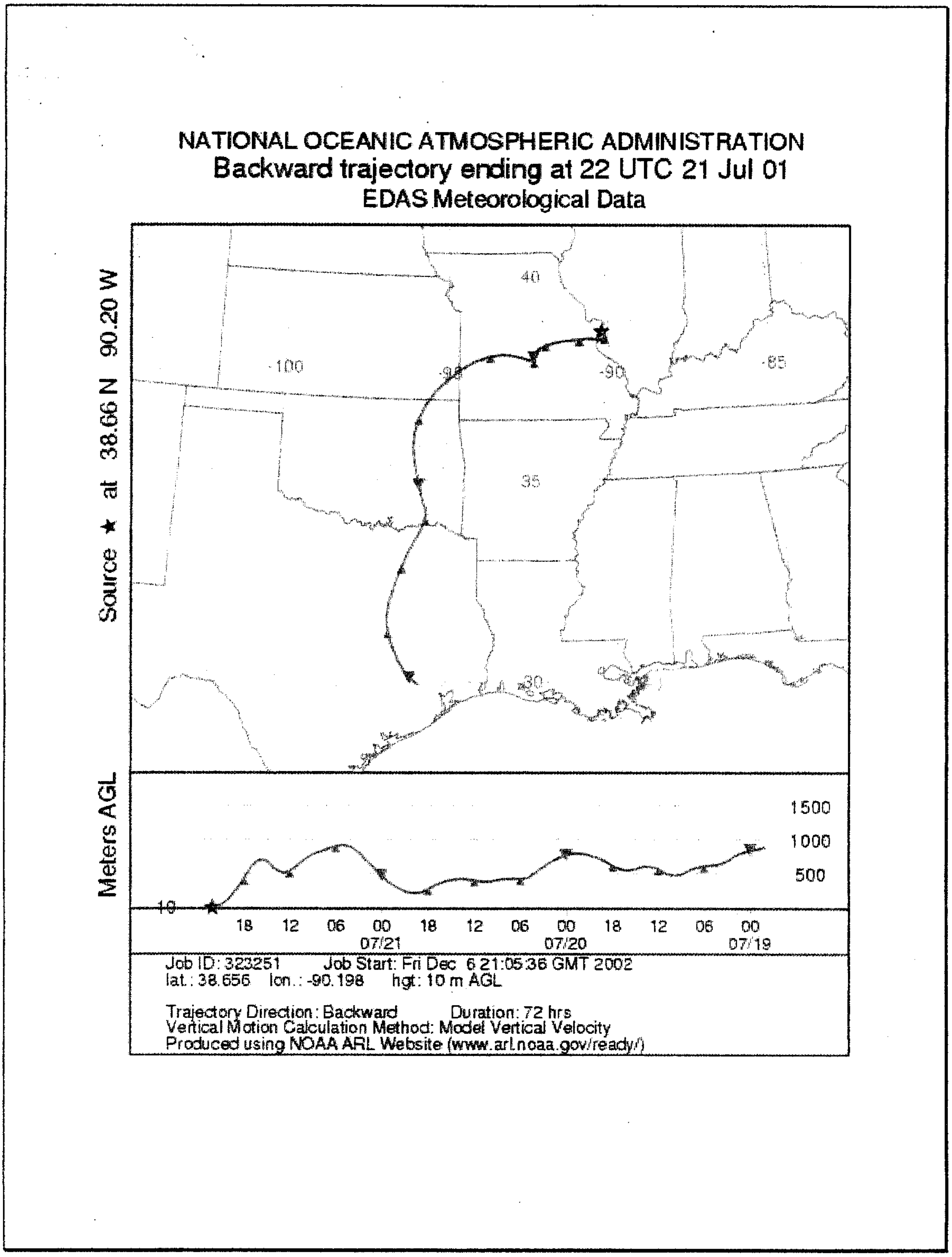


Figure A-2. Grant School mass = 35.85 μg/m^3 and sulfate = 12.21 μg/m^3.

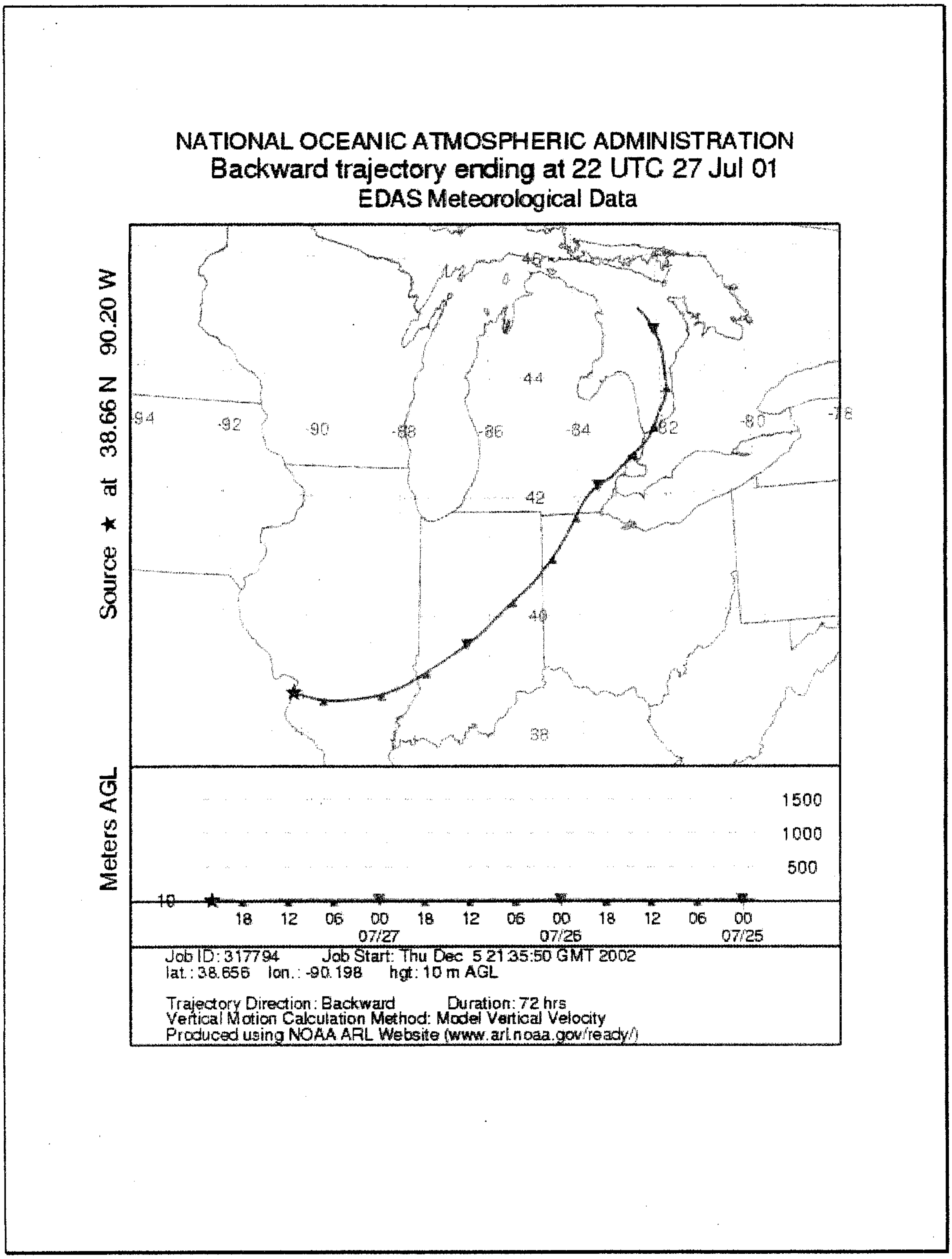


Figure A-3. Blair St. sulfate = 12.76 μg/m^3. Grant School sulfate = 13.53 μg/m^3 and ammonium = 5.16 μg/m^3.

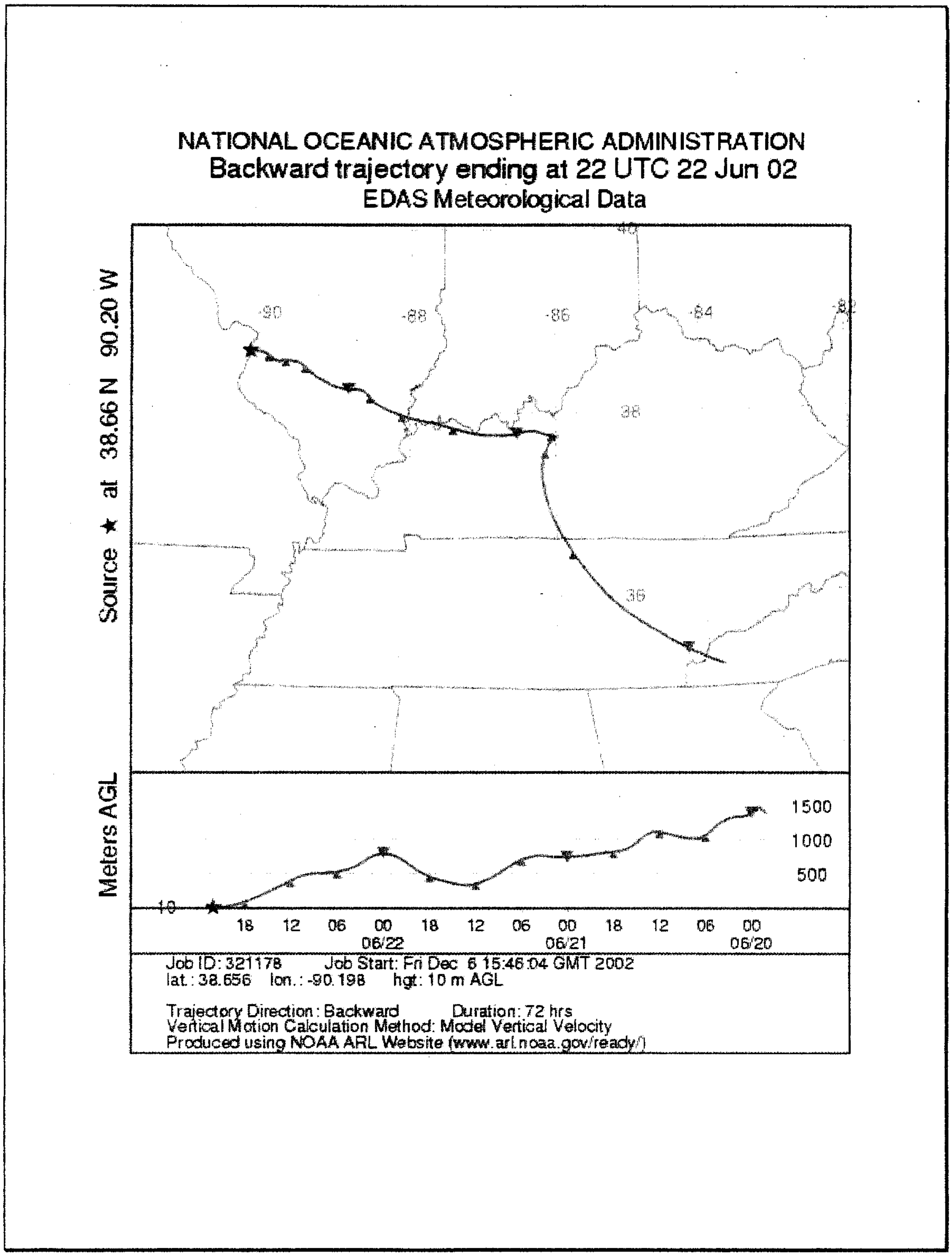


Figure A-4. Blair St. mass = 44.00 $\mu g/m^3$, sulfate = 17.00 $\mu g/m^3$, and organic carbon = 11.04 $\mu g/m^3$. Grant School mass = 41.70 $\mu g/m^3$, sulfate = 17.61 $\mu g/m^3$, ammonium = 5.77 $\mu g/m^3$, and organic carbon = 9.76 $\mu g/m^3$.

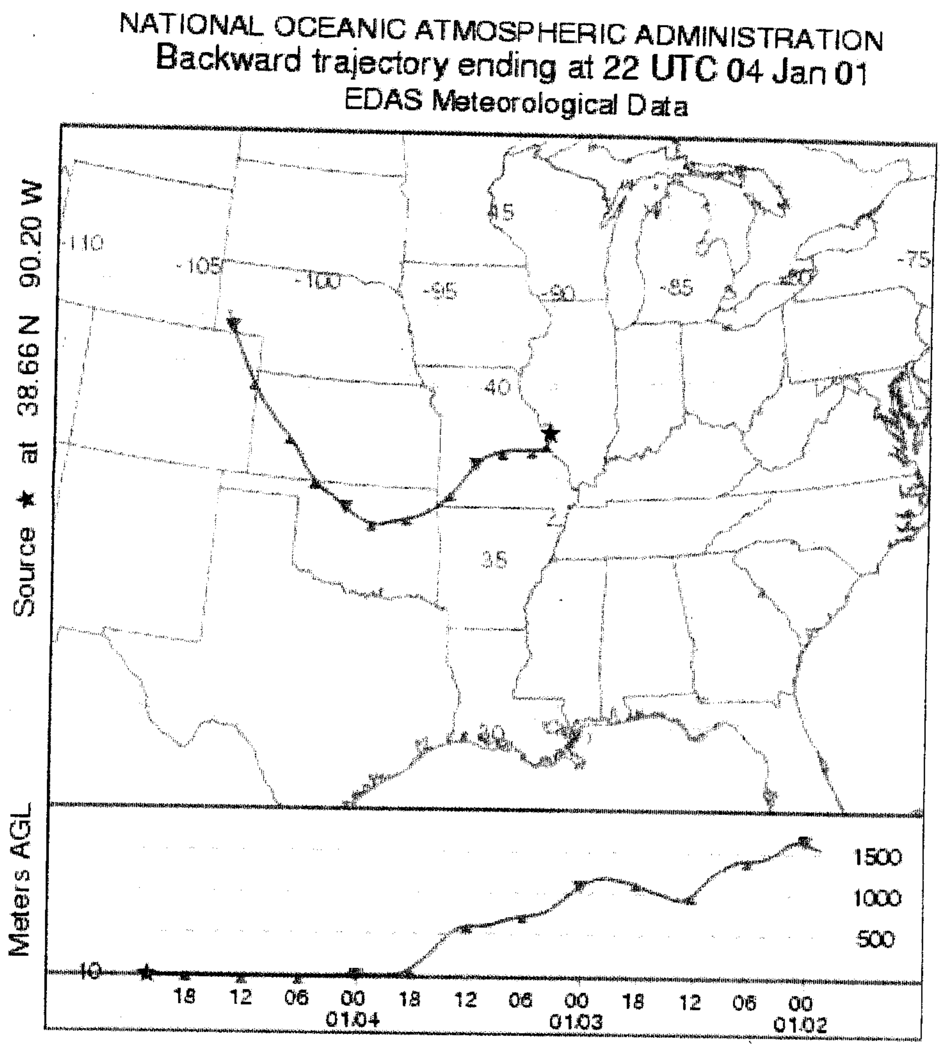


Figure A-5. Blair St. mass = 38.16 μg/m^3 and ammonium = 6.05 μg/m^3.

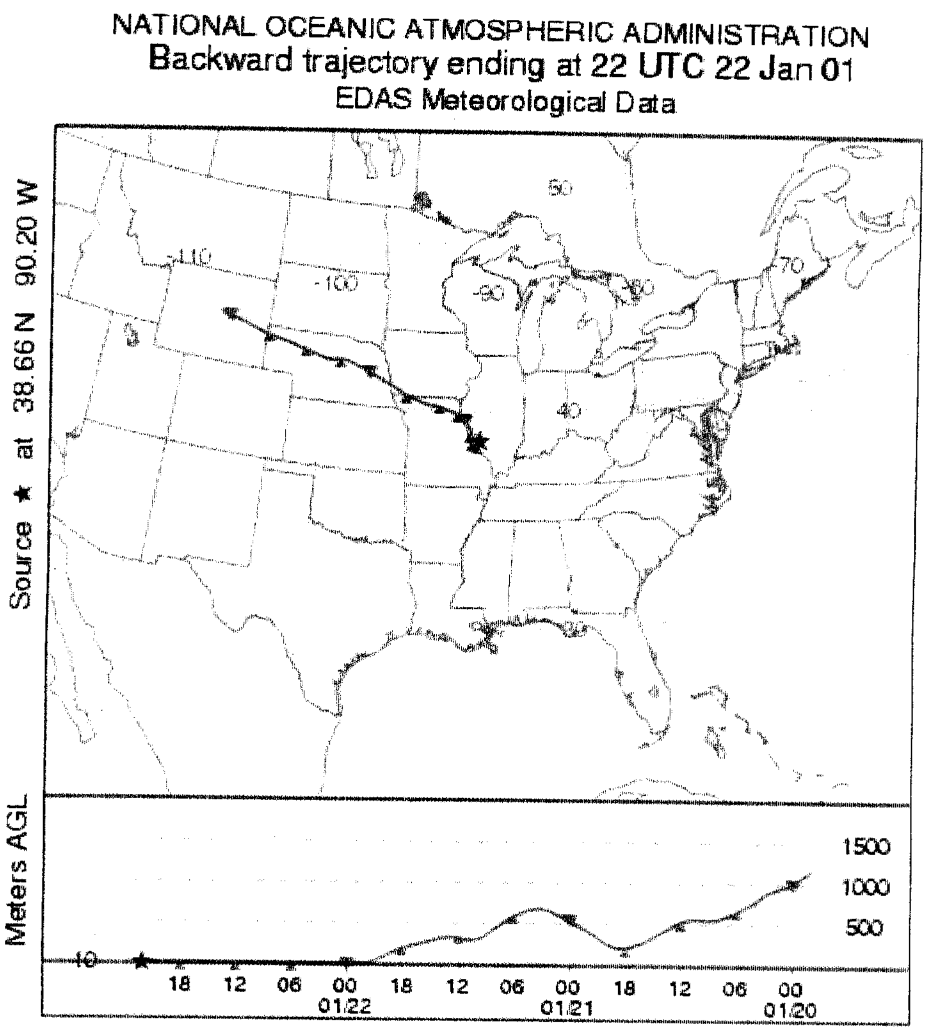


Figure A-6. Blair St. mass = 41.17 μg/m^3, nitrate = 13.26 μg/m^3, ammonium = 5.60 μg/m^3, and organic carbon = 12.70 μg/m^3.

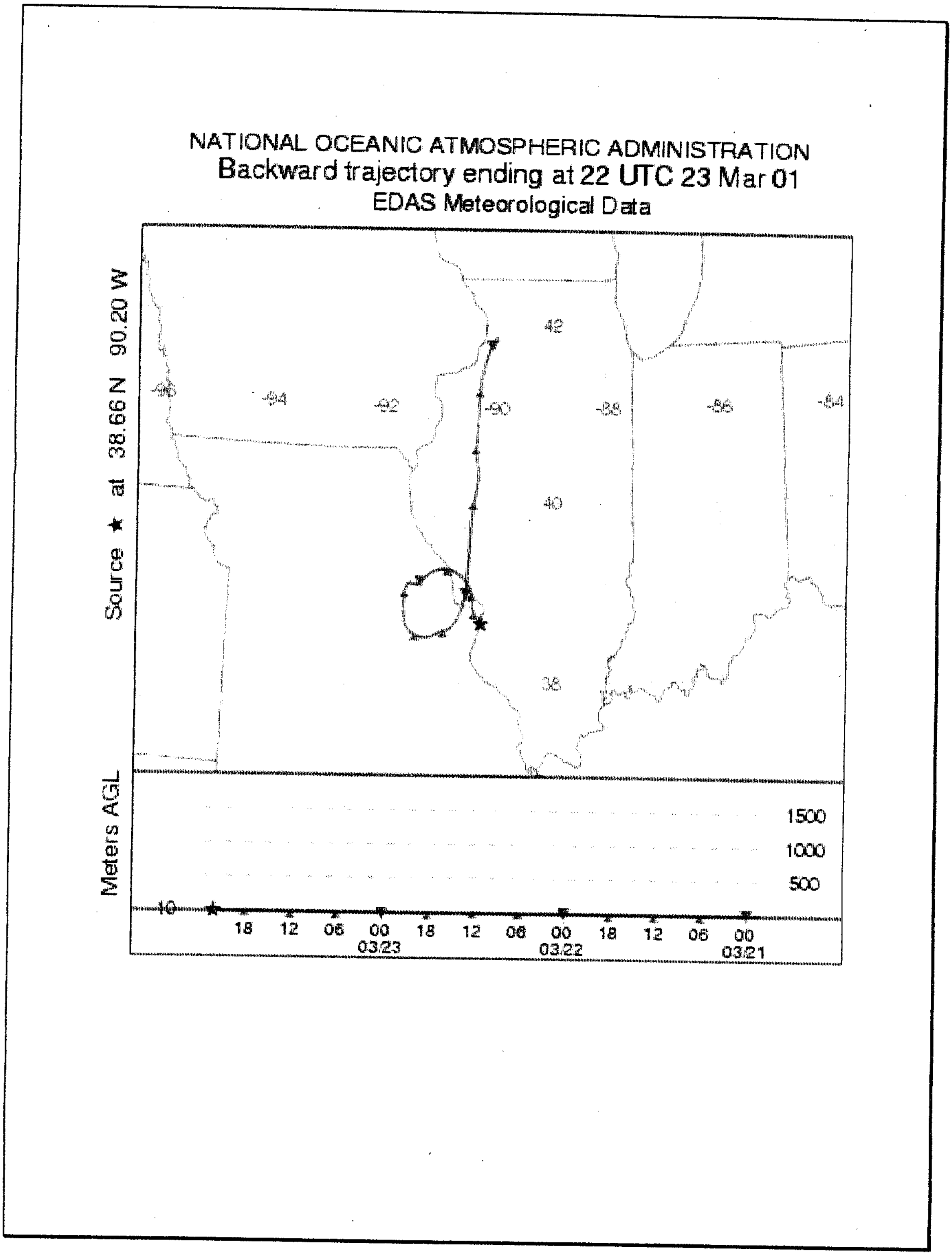


Figure A-7. Blair St. nitrate = 14.01 μg/m^3 and ammonium = 6.83 μg/m^3.

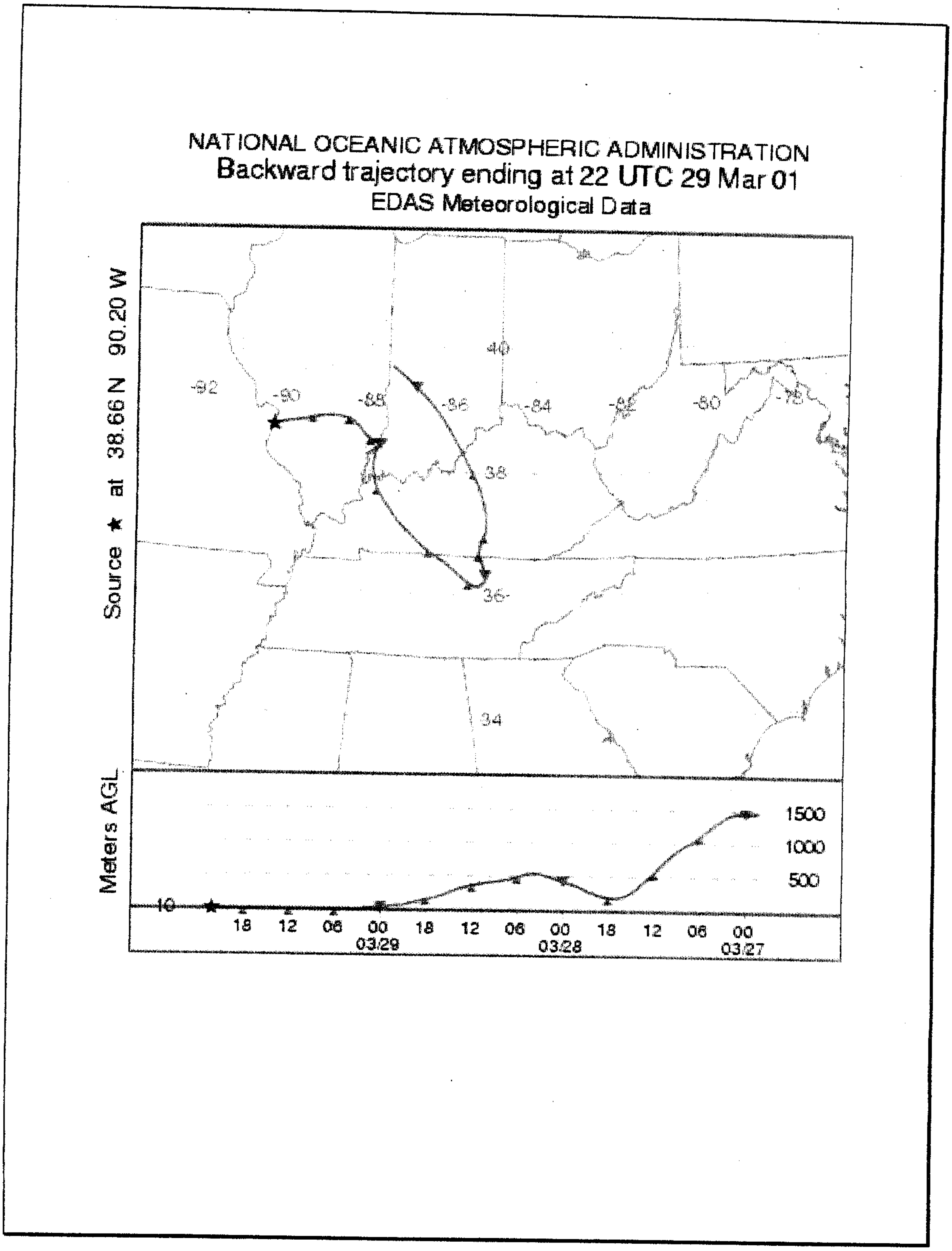


Figure A-8. Blair St. mass = 35.71 μg/m³, nitrate = 12.25 μg/m³, and ammonium = 5.69 μg/m³.

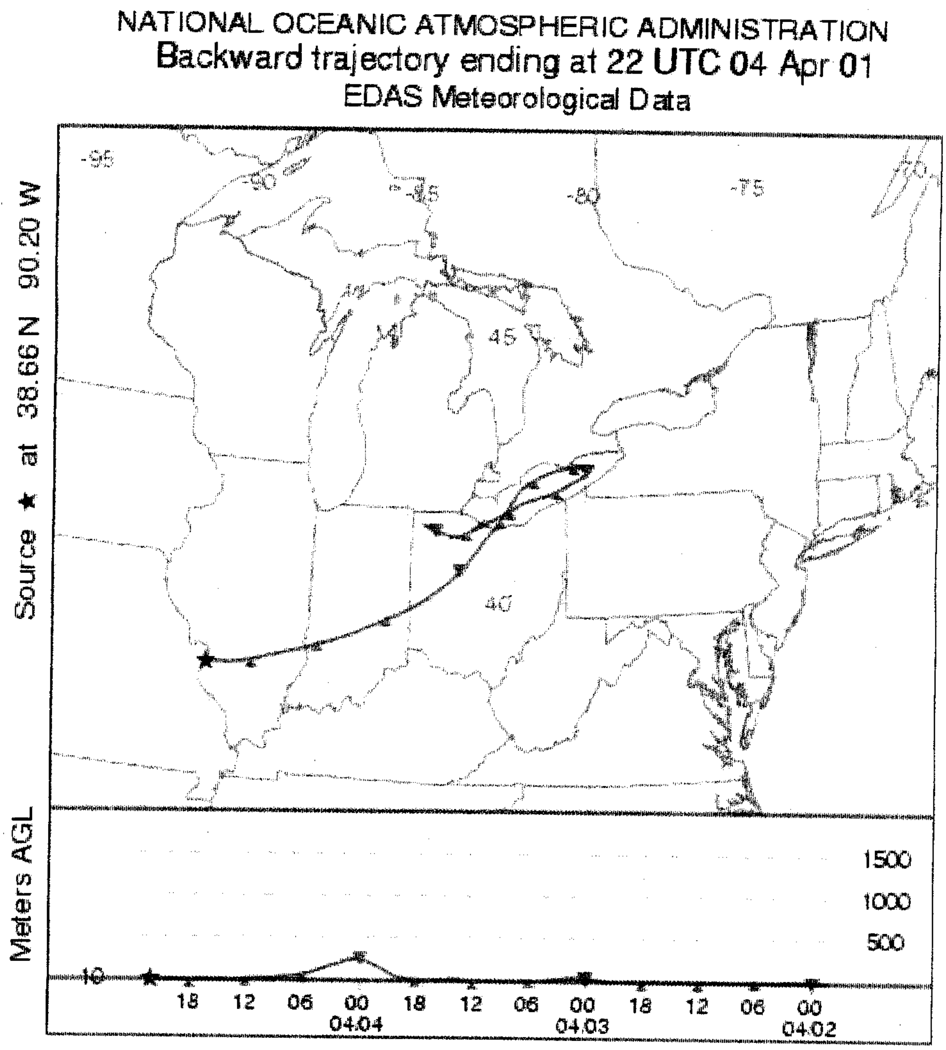


Figure A-9. Blair St. mass = 35.16 μg/m^3, nitrate = 13.87 μg/m^3, and ammonium = 7.19 μg/m^3.

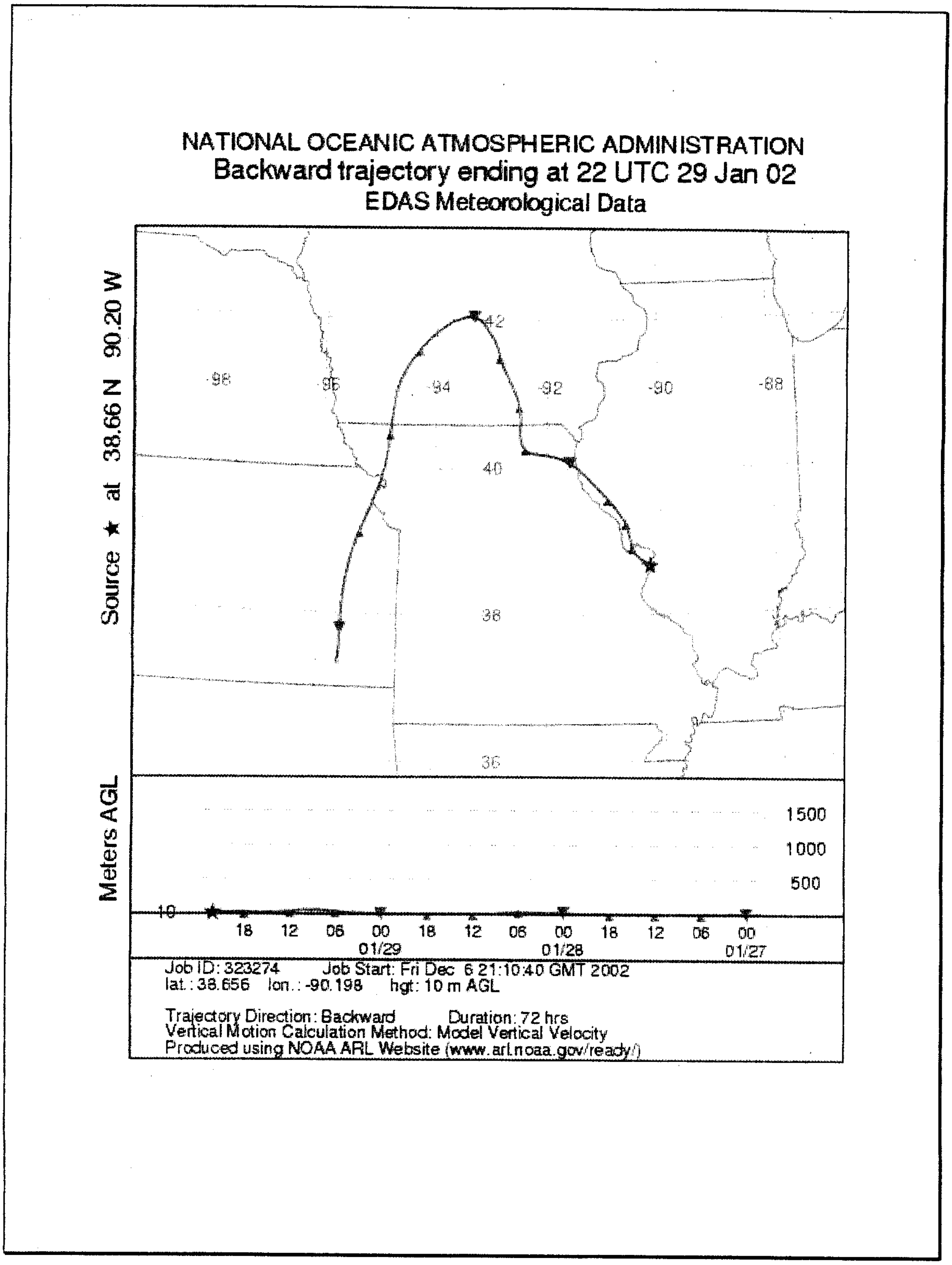


Figure A-10. Grant School. mass = 35.67 μg/m^3 and nitrate = 8.95 μg/m^3,

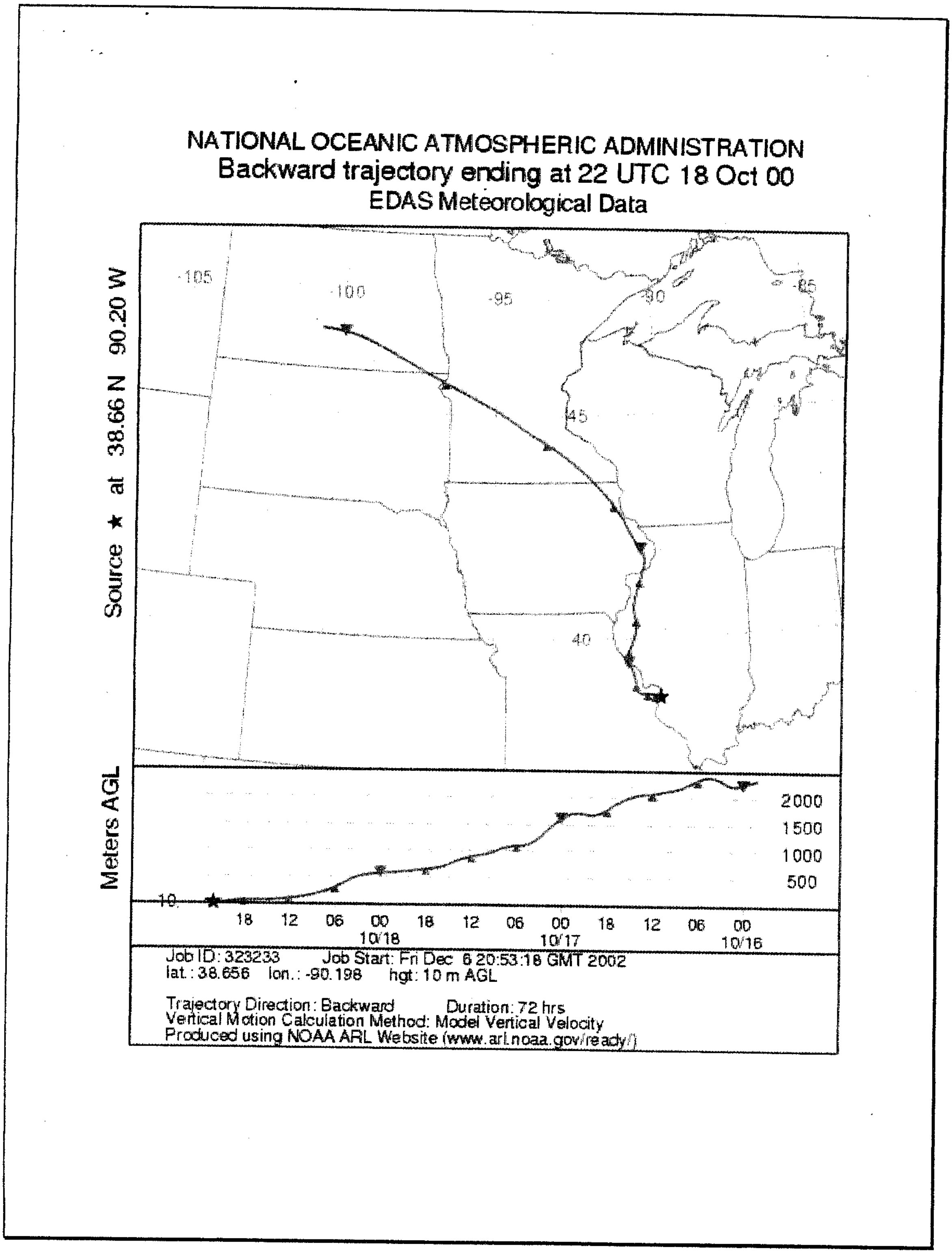


Figure A-11. Blair St. organic carbon = 11.58 μg/m³ and elemental carbon = 2.80 μg/m³.

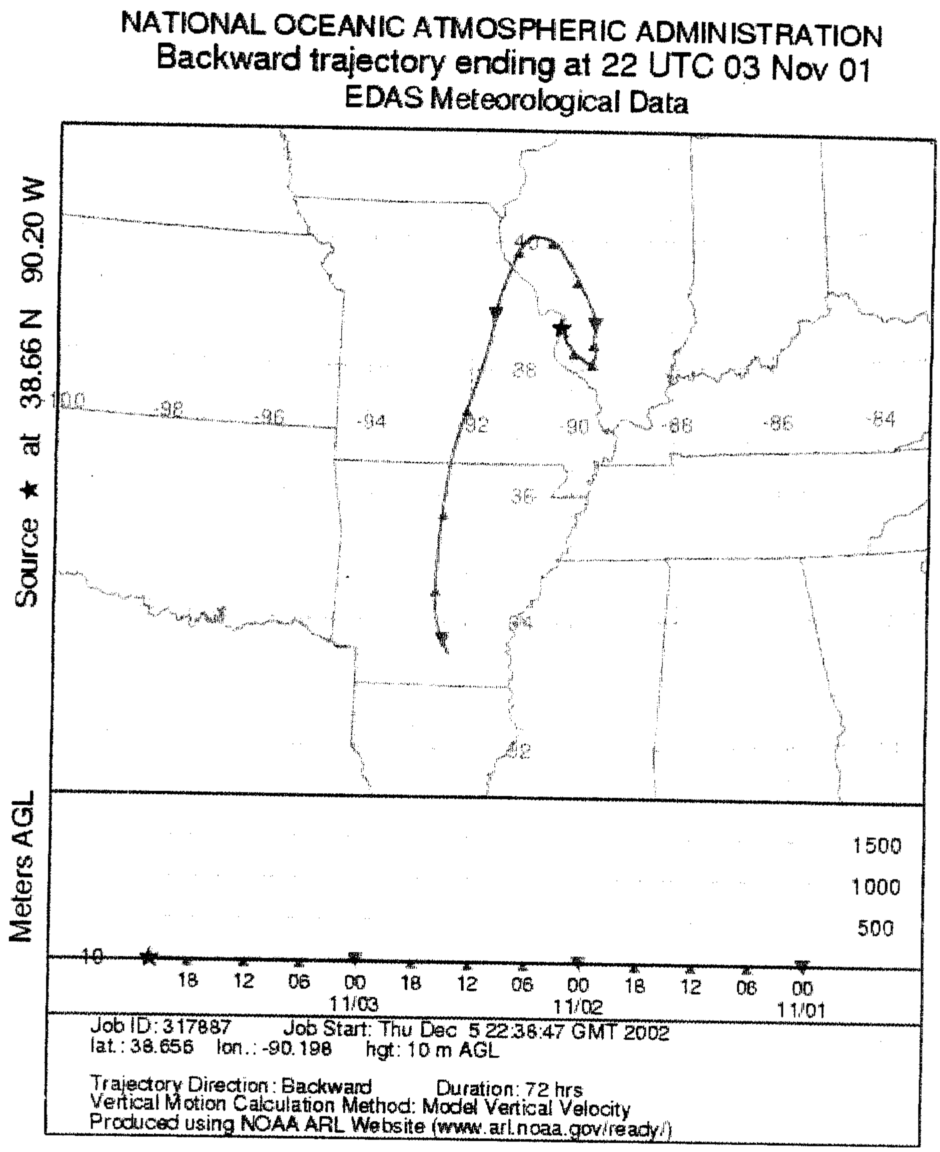


Figure A-12. Blair St. organic carbon = 10.43 μg/m^3 and elemental carbon = 2.64 μg/m^3. Grant School organic carbon = 13.96 μg/m^3 and elemental carbon = 3.07 μg/m^3.

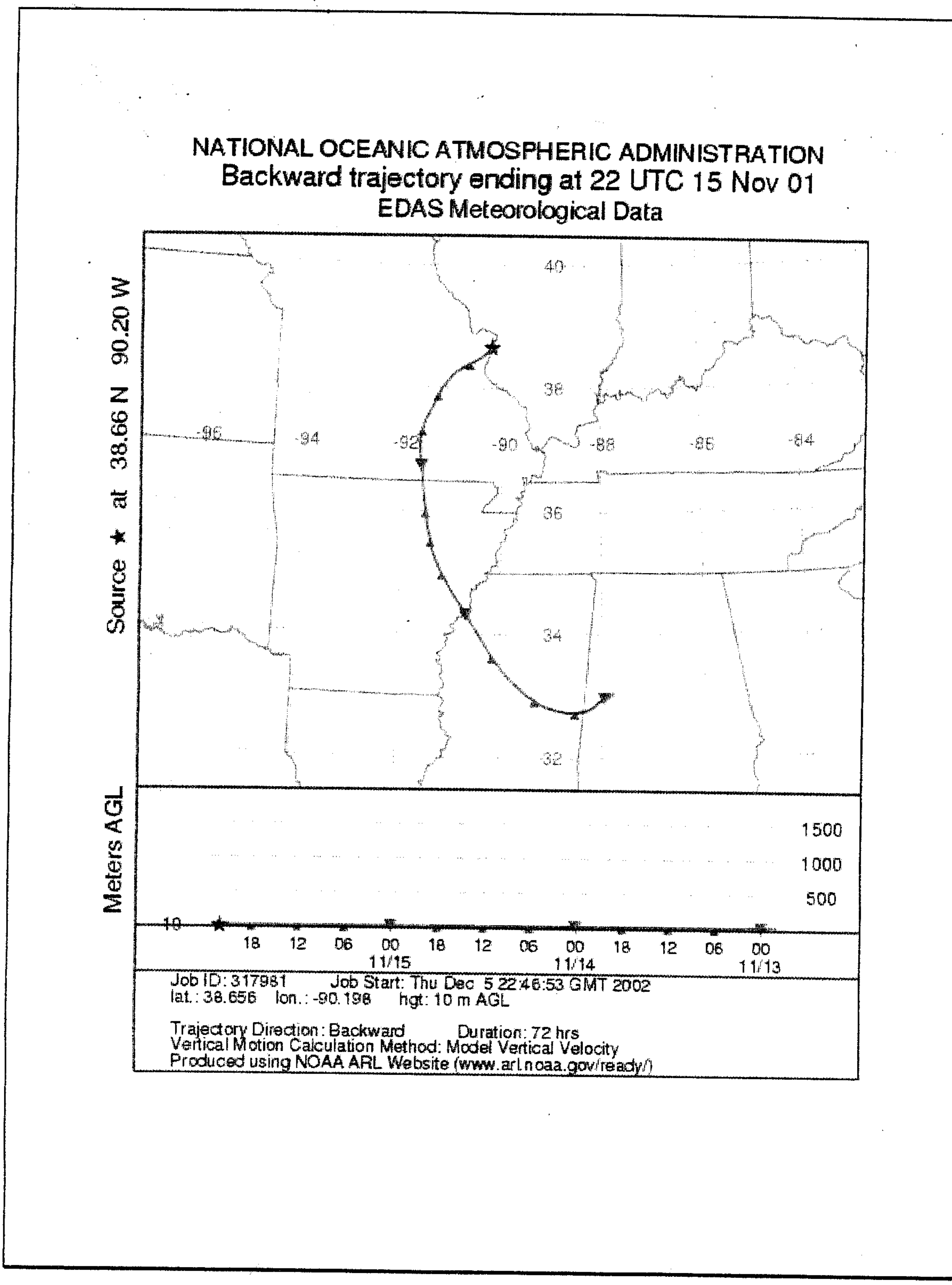
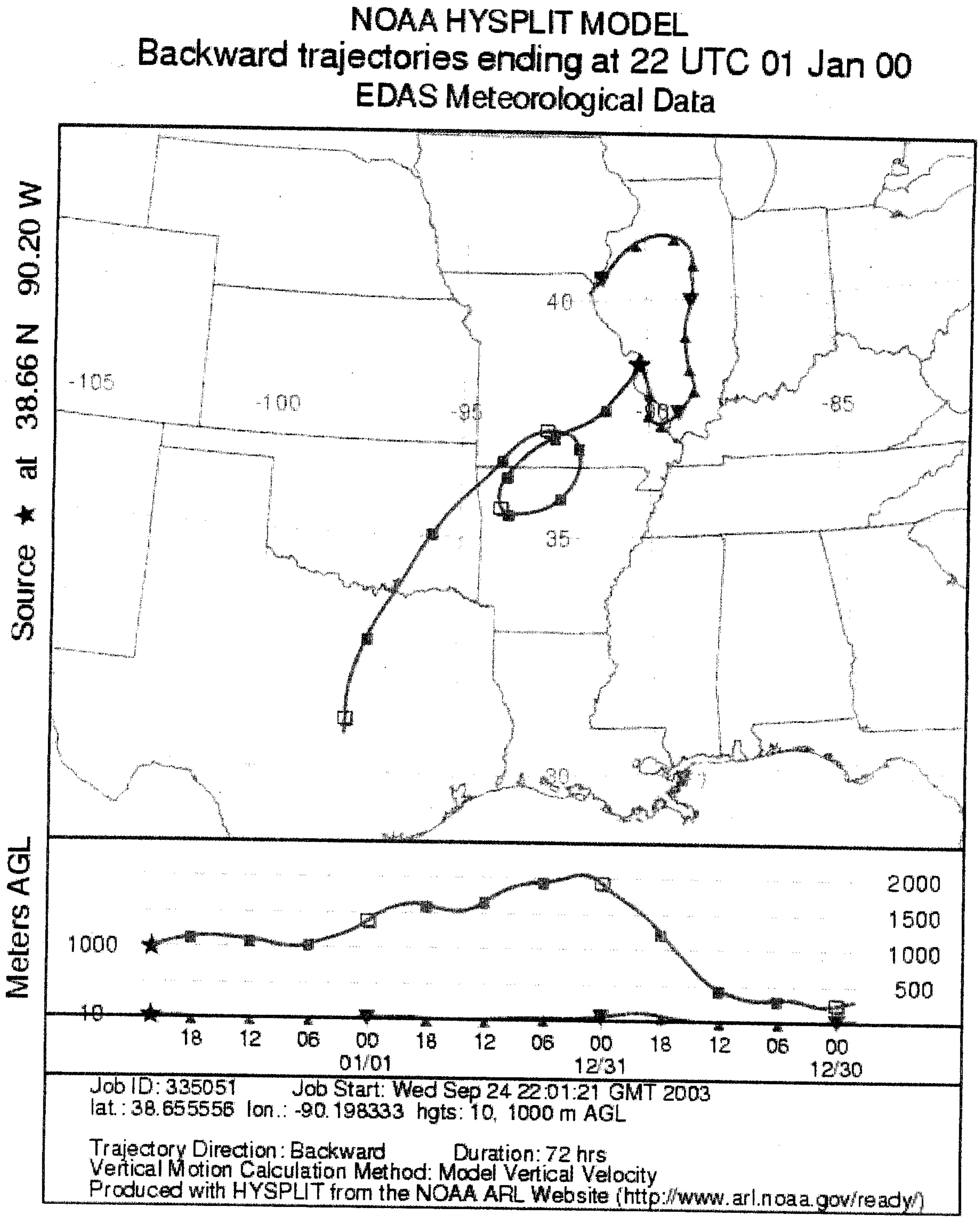


Figure A-13. Blair St. organic carbon = 11.36 μg/m^3. Grant School organic carbon = 10.63 μg/m^3 and elemental carbon = 1.90 μg/m^3.

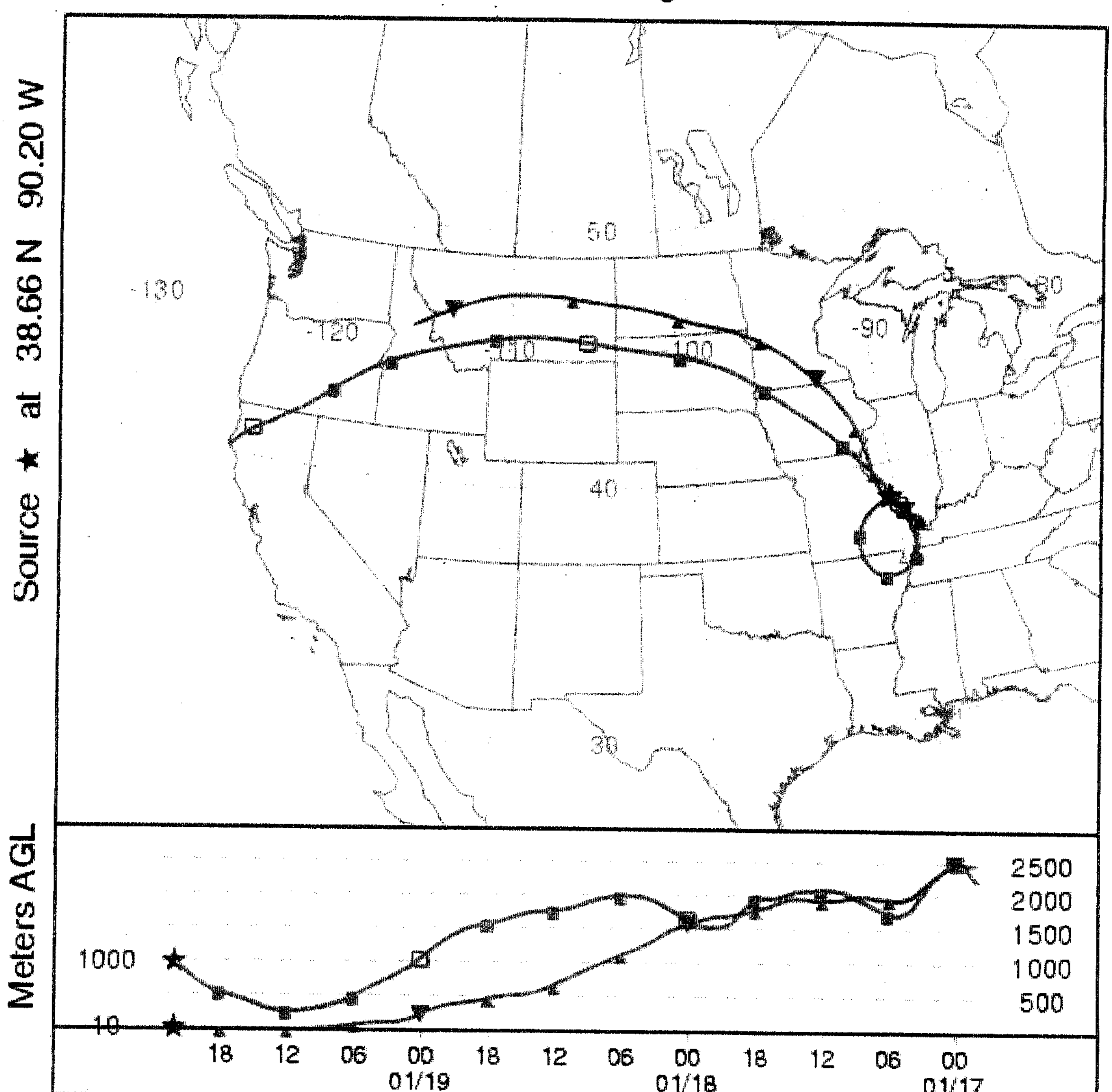
Table A-1. Days with PM2.5 Concentration Greater than 25 ug/m3 at One or More St. Louis Area Sites, 2000 and 2001

	MO	W. Alton	Margaretta	Blair St	S.Broadway	Ferguson	Clayton AS	Sunset Hills	Arnold	IL	Alton	Wood River	Granite City	E St. Louis	Swansea
01-Jan-00	X	30.4	23.3	24.3		36.8	23.8		17.5	X	30.2	27.5	23.5	25.2	24.6
19-Jan-00		21.5		22.8		20.9	21.0		20.2	X	19.8	20.6	29.3	21	20.3
31-Jan-00	X	24.5	16.3	25.1		27.2	27.6		22.8	X	26.8	28.8	27.5	29.9	28.1
09-Feb-00		24.9	18.3	17.6		16.4	18.7		17.0	X	22.1	21.1	25.2	18.7	20.1
15-Feb-00	X	27.7	22.3	23.5		21.3	23.3		21.2	X	24.3		26.3		
07-Mar-00	X	19.9	18.2	20.8		18.0	51.0		18.6		22.8	20.6	22.3	19.5	17.9
16-Mar-00	X	10.2	10.0	13.7		11.1	27.8		15.5		11.7	21.6	12.4		
31-Mar-00	X	18.1	25.3	27.4	23.1	19.3	20.7		18.8	X	21.9	20.5	22.4	29.3	20
30-Apr-00		17.5	17.3	17.3	17.9	16.5	17.2		19.5	X		17.2	20.7	21.8	25.2
12-May-00		23.2	22.4	22.8	22.3	21.8	21.1		22.7	X	23.9	26.1	30.3	24.6	35.5
02-Jul-00		20.2		21.5	22.7	19.5	19.6		22.8	X	22.1	22.9	26	26.8	19
05-Jul-00	X	21.6	23.9	24.3	25.5	21.5	24.6		27.4		23	23.7	22	24	20.9
08-Jul-00	X	26.4		24.1	23.5	24.8	24.3		27.6	X	27.8	26.8	30.7	25.1	26.8
26-Jul-00	X	34.8	33.5	34.8	34.0	33.3	33.4		33.1	X	36.3		13.4	36.1	32.6
16-Aug-00	X	25.5	28.1	30.3	31.3	28.6	29.9		32.7	X	25.1	27.3	25.7	32	
22-Aug-00	X	34.4	32.6	34.3	31.8	32.2	30.8		34.8	X	36	36.1	33.5	34.3	
28-Aug-00	X	24.4	24.4	25.6	22.2	23.8	19.6		22.4	X	26	25.2	25.3	24.2	21.6
31-Aug-00	X	25.9	25.0	27.0	25.0	26.4	24.5		28.8	X	26.4	24.8	29.7	26.2	22.6
03-Sep-00	X	35.2	36.9	36.8	37.3	37.7	34.1		36.6	X	37.5	37.4	41.3	40.8	35.3
03-Oct-00	X	20.6	21.4	34.0	21.9	20.0	19.8		20.5		23.8	22.6	24.7	24.4	
21-Oct-00	X	32.0	27.8	29.1	28.4	27.1	27.3		23.9	X	36.6	32.1	31.5	33.7	31.7
24-Oct-00		16.5	20.8	23.3	22.5	17.9	17.6		20.0	X	19.2	20.3	21.6	28.1	21.4
27-Oct-00		16.4	17.9	18.8	22.1	15.0	16.9		17.0	X	17	26.1	20.3	28.2	18.8
30-Oct-00		16.8	16.7	18.9	15.9	17.4	16.0		18.8	X	18.7	16.6	37.1	41	
02-Nov-00		14.3	18.4	19.5	20.0	13.4	16.2		21.8	X	18.5	20.9	22.7		32.8
23-Nov-00		18.0	22.0	22.7	19.9	20.5	22.6		22.4	X	19.4	18.1	26	27.5	18.6
26-Nov-00	X	27.8	27.2	26.2	30.3	26.3	26.3		27.1	X		28.9	23.4	26.4	27.5
14-Dec-00	X	27.1	26.5	31.0	26.5	28.3			22.5	X	28.4	25.7	28.1	22.2	24.4
26-Dec-00	X	21.6	25.6	27.1	28.5	22.5	27.7		26.4		21	20.6	28	19.1	11.9
01-Jan-01	X	14.8		20.5	22.8	22.7	28.1		26.4		15.6				24.8
04-Jan-01	X	36.5	35.8	37.0	40.0	34.4	33.8		32.6	X	39.6	5.1			36.4
10-Jan-01	X	33.3	15.0	16.6	16.0	15.0	18.5		14.5	X	28.1	21.4	23.3	20.8	
16-Jan-01		11.9	10.9	11.2	13.2	10.1	13.2		14.9	X	12.4	12.5	30.7	22.8	
19-Jan-01		23.3	21.4	22.4	22.0	20.5	20.5		24.0	X	23.4	24.2	23.4	26.8	26
22-Jan-01	X	36.7	37.4	41.4	39.4	36.1	36.0		36.8	X	38.1	36.5	40.8	52.2	39.5
25-Jan-01		22.3	18.6	20.3	16.7	19.6	18.1		18.4	X	19.8	18.2	21	25.7	
28-Jan-01	X	32.0	28.1	26.4	24.1	25.8	25.8		25.0	X	25.1	25.1	29.2	29.8	
08-Mar-01		20.8	20.5	21.8	21.0	18.6	19.2		20.7	X	23.2	21.4	25.9	24	13.5
11-Mar-01	X	30.5	28.2	28.9	29.2	24.1	25.7		29.8	X	29.7	26.3	21.6	31.6	35.1
23-Mar-01	X	31.3	29.5	33.7	30.7	28.2	27.2			X		30.7	32.4	30.2	35
29-Mar-01	X	34.7	33.7	36.3	32.6	30.2			31.8	X	32.5	31.6	31.6	36.6	37.8
04-Apr-01	X	42.0	34.5	37.3		32.7	33.6		30.8	X	34.4	33.6	29.8	20.9	41.8
07-Apr-01		13.8	14.8	16.2	16.1	14.1	13.7		17.1	X	16.2	15.1	26.6	18.6	17.8
09-Jun-01	X	15.8	21.2	24.1	28.6	19.6	22.7	25.5	27.7	X		17.7			26.2
12-Jun-01	X	31.2	29.2	31.2	31.1	28.5	29.6	28.1	32.1	X		32	32.3		39.3
27-Jun-01	X	31.0	28.2	29.9	28.0	31.0	29.0	24.8	27.3	X	35.9	20.4	31.9	32.9	
03-Jul-01		14.7	13.8	15.0	13.6	14.3	13.7	12.9	13.4	X	15.7	26.2	17.5	18.7	
21-Jul-01	X	26.8	26.3	27.7	26.2	24.7	21.6	23.0	23.0	X	43.1	28.2	29.4		25.6
27-Jul-01	X	25.4	24.7	28.5	25.7	24.4	24.8	23.2	26.0	X		25.5	27	28.3	28.2
08-Aug-01	X	31.4	25.7	26.2	22.0	28.7	26.0	20.1	21.4	X	34.5	33.9	27.3	29.7	26.9
29-Aug-01	X	20.5	26.2	22.6	21.4	20.6	20.6	18.0	19.8		18.2	18.6	19.3		19.8
04-Sep-01	X	19.7	25.0	26.6	25.7	22.9	23.8	24.0	26.4	X	23		30.4	26.5	33.9
13-Sep-01	X	16.8	23.1	25.8	23.8	19.5	20.7	22.1	22.7	X	22.6	21.8	25.9	23.9	
22-Oct-01		20.2	18.0	19.1		17.3	18.1	16.5	18.8	X	26.7	22.4	25.6	18.5	19
03-Nov-01		10.5	19.5	19.6	19.7	9.0	10.7	9.3	10.9	X	25.4	23	18.2	22.6	26.7
15-Nov-01	X	32.0	30.9	32.7	34.4	28.1	29.2	26.3	29.4	X	35.5	35.7	34.3	33.4	
18-Nov-01	X	32.9	26.7	30.3	28.5	27.2	25.2	23.4		X	40.9	32.8	36.4	30.8	22.8



NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 01 Jan 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-105
-100
-95
-85
40
35
30
Meters AGL
1000
10
2000
1500
1000
500
18 12 06 00 18 12 06 00 18 12 06 00
01/01
12/31
12/30
Job ID: 335051 Job Start: Wed Sep 24 22:01:21 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 19 Jan 00
EDAS Meteorological Data



Job ID: 334990 Job Start: Wed Sep 24 21:57:27 GMT 2003
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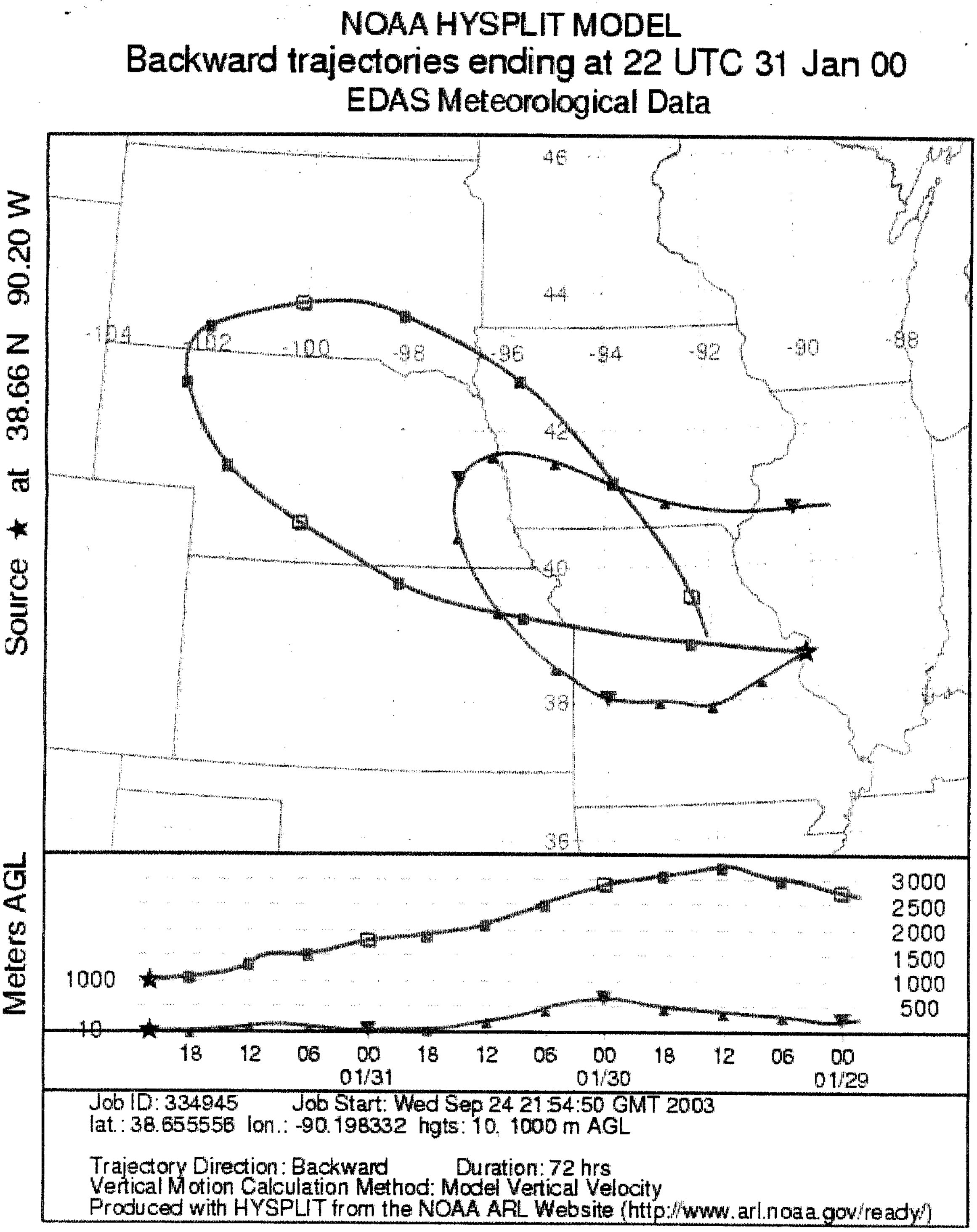
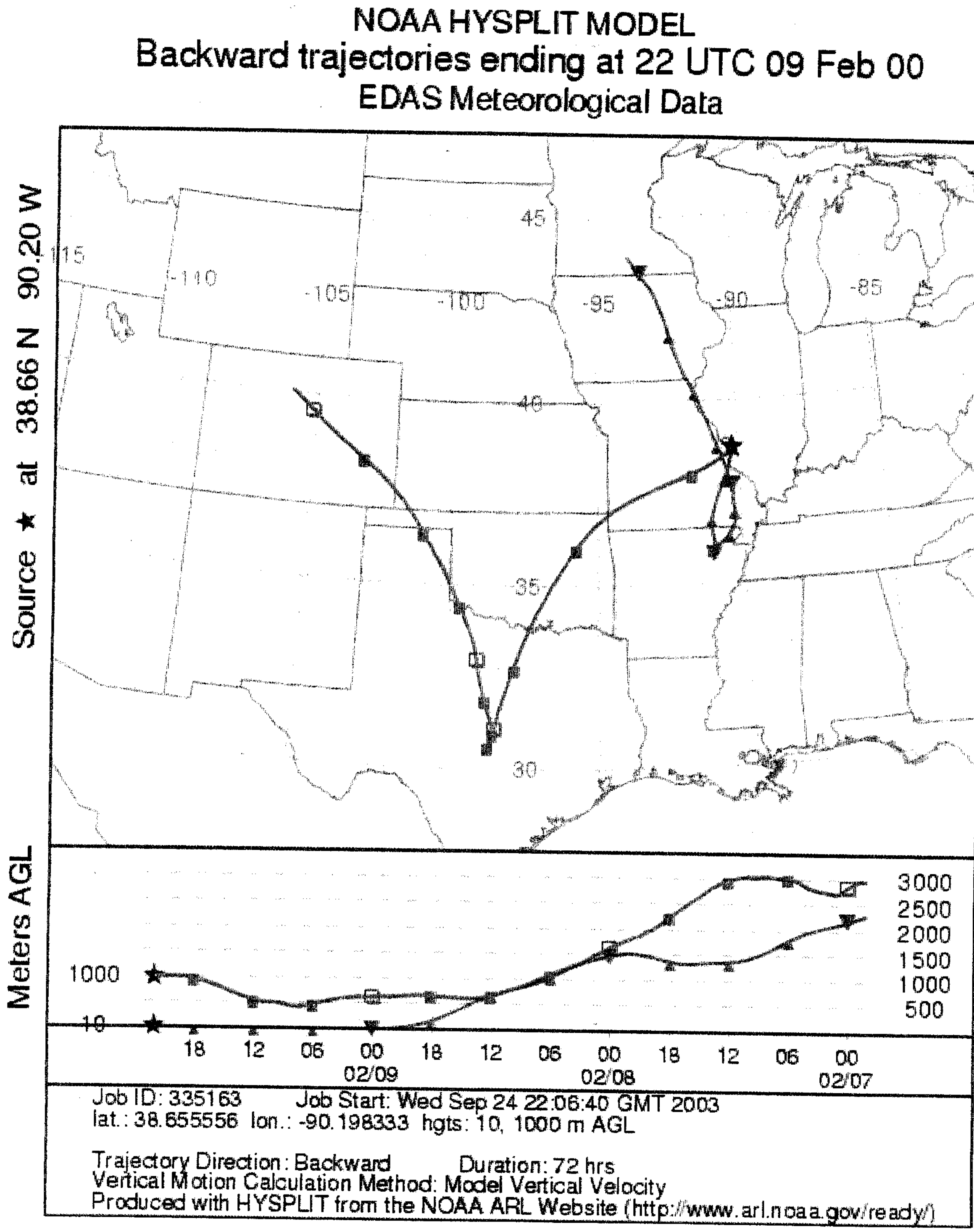
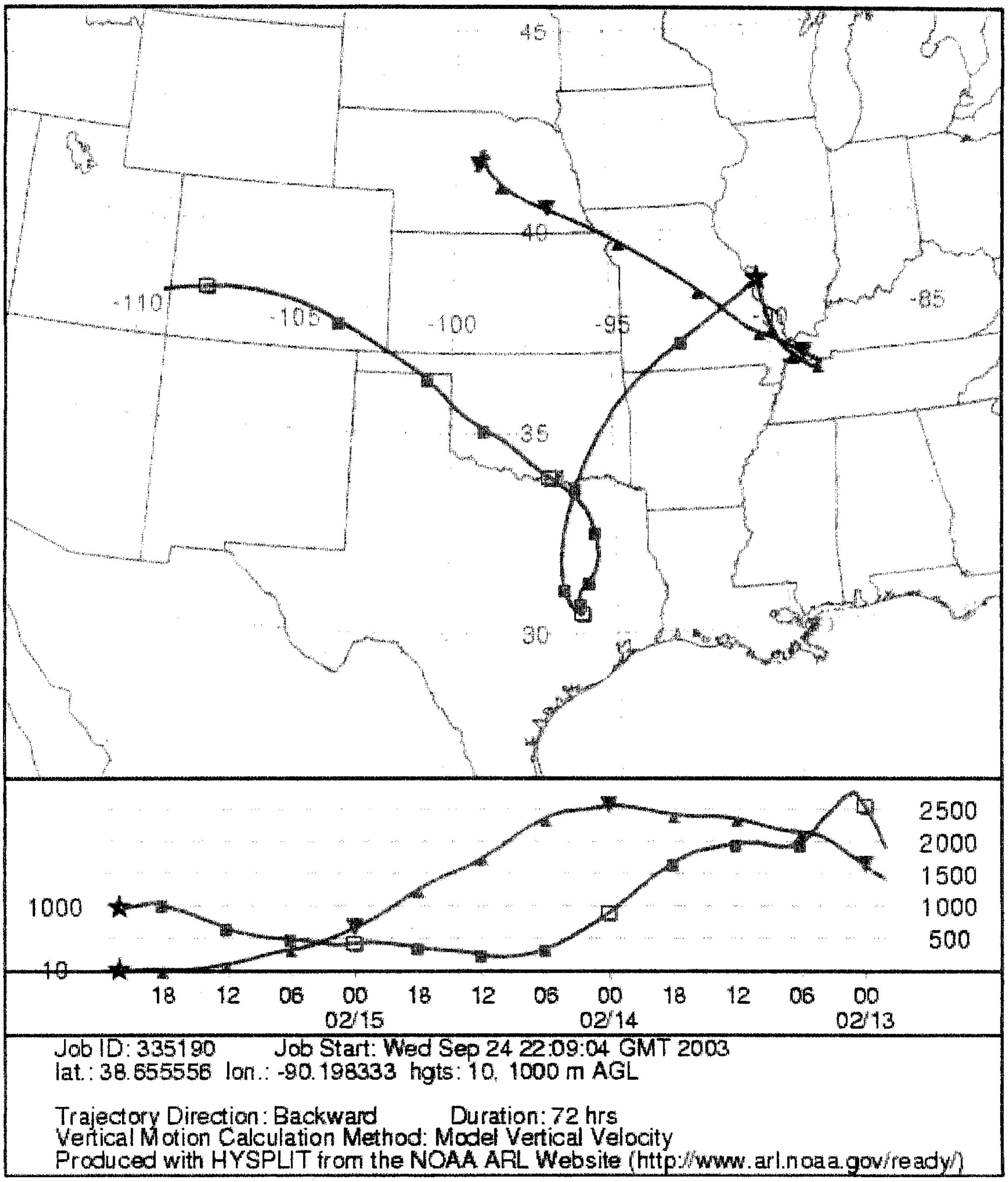
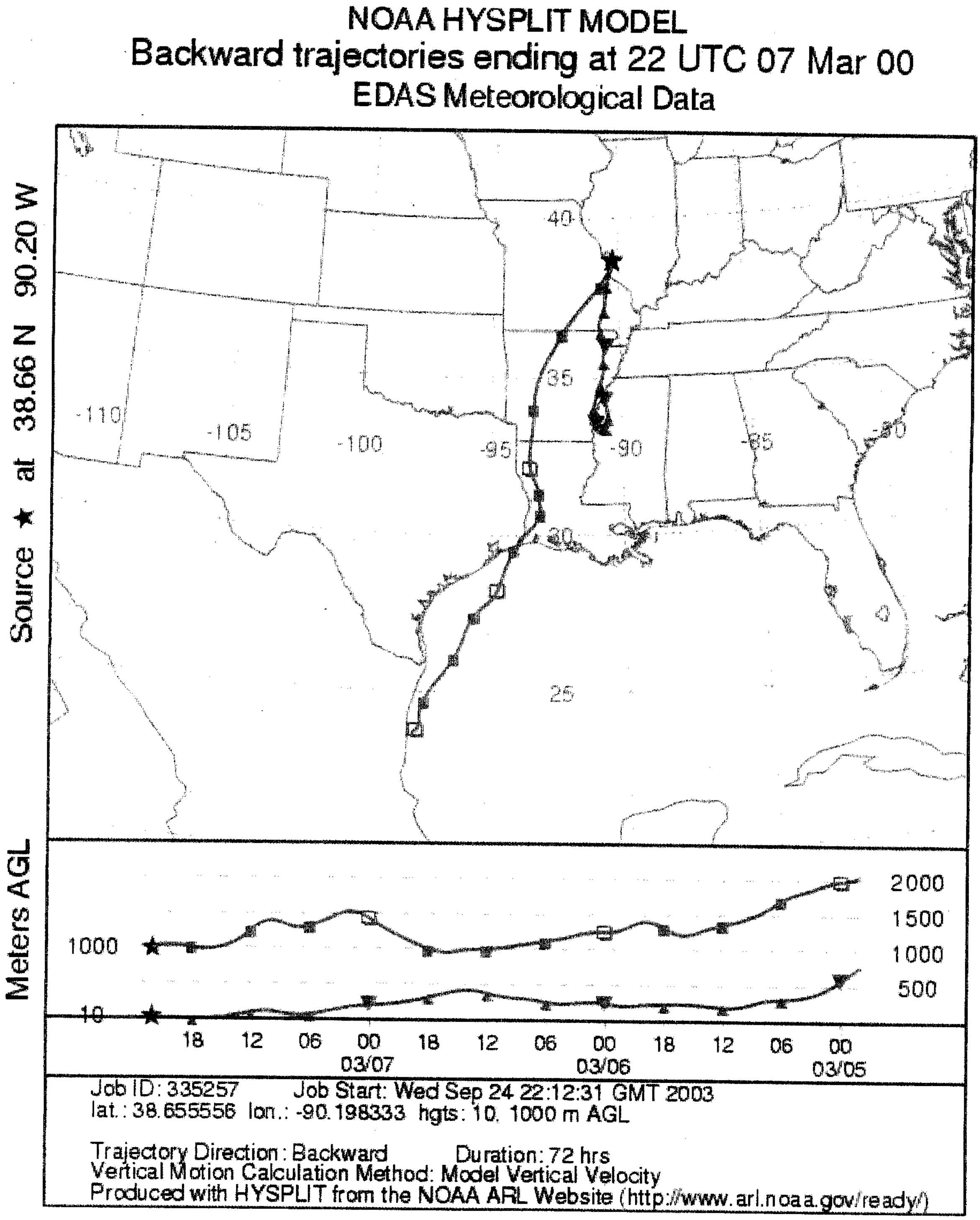
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 31 Jan 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
Meters AGL
46
44
42
40
38
36
-104
-102
-100
-98
-96
-94
-92
-90
-88
3000
2500
2000
1500
1000
500
1000
10
18 12 06 00 18 12 06 00 18 12 06 00
01/31
01/30
01/29
Job ID: 334945 Job Start: Wed Sep 24 21:54:50 GMT 2003
lat.: 38.655556 lon.: -90.198332 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

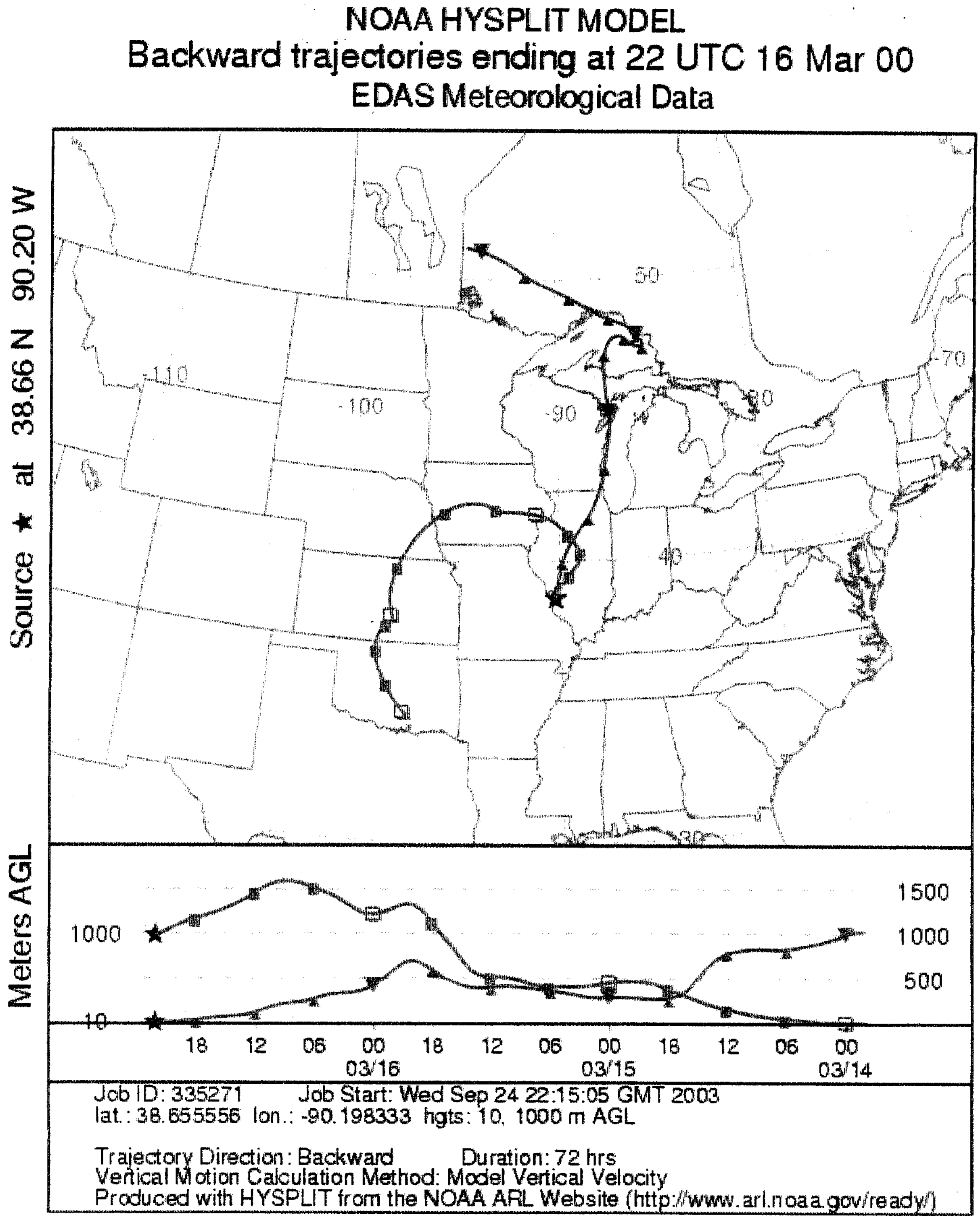

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 09 Feb 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
45
-110
-105
-100
-95
-90
-85
40
35
30
Meters AGL
1000
10
3000
2500
2000
1500
1000
500
18
12
06
00
02/09
18
12
06
00
02/08
18
12
06
00
02/07
Job ID: 335163 Job Start: Wed Sep 24 22:06:40 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 15 Feb 00
EDAS Meteorological Data



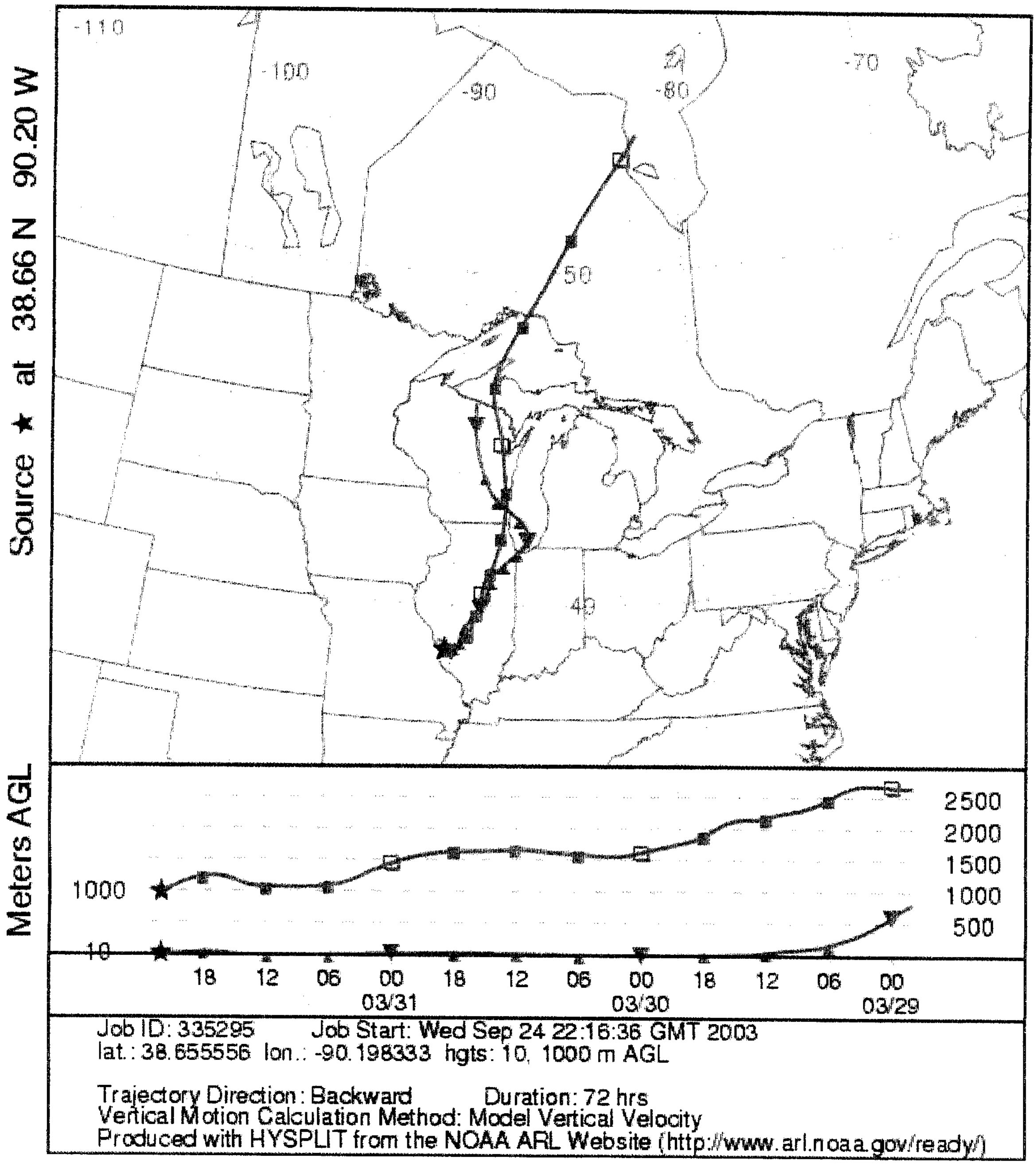


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 07 Mar 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
40
35
30
25
-110
-105
-100
-95
-90
-85
-80
Meters AGL
1000
10
2000
1500
1000
500
18
12
06
00
03/07
18
12
06
00
03/06
18
12
06
00
03/05
Job ID: 335257 Job Start: Wed Sep 24 22:12:31 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

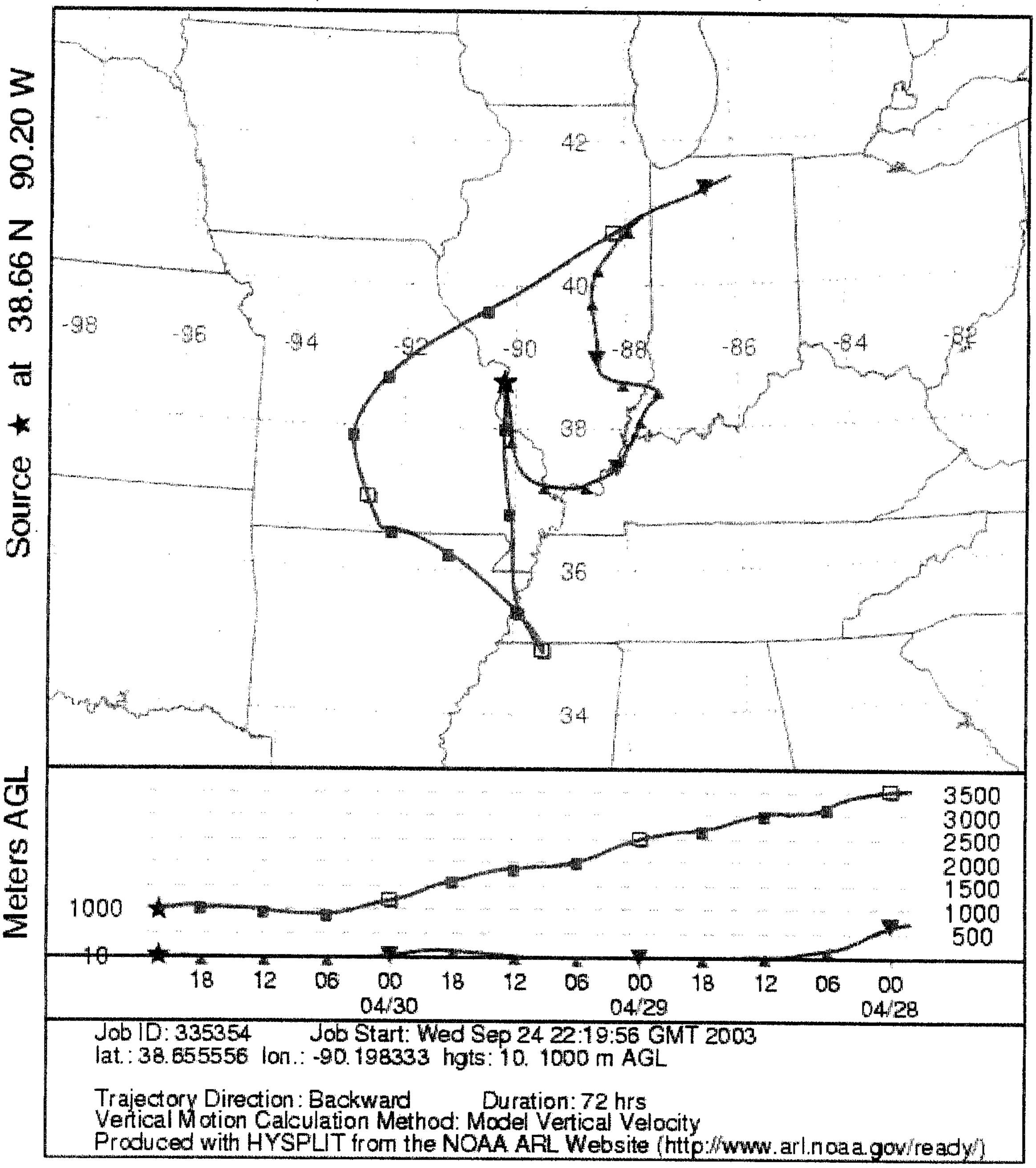


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 16 Mar 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-110
-100
-90
-80
-70
50
40
Meters AGL
1500
1000
500
10
18 12 06 00 18 12 06 00 18 12 06 00
03/16
03/15
03/14
Job ID: 335271 Job Start: Wed Sep 24 22:15:05 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

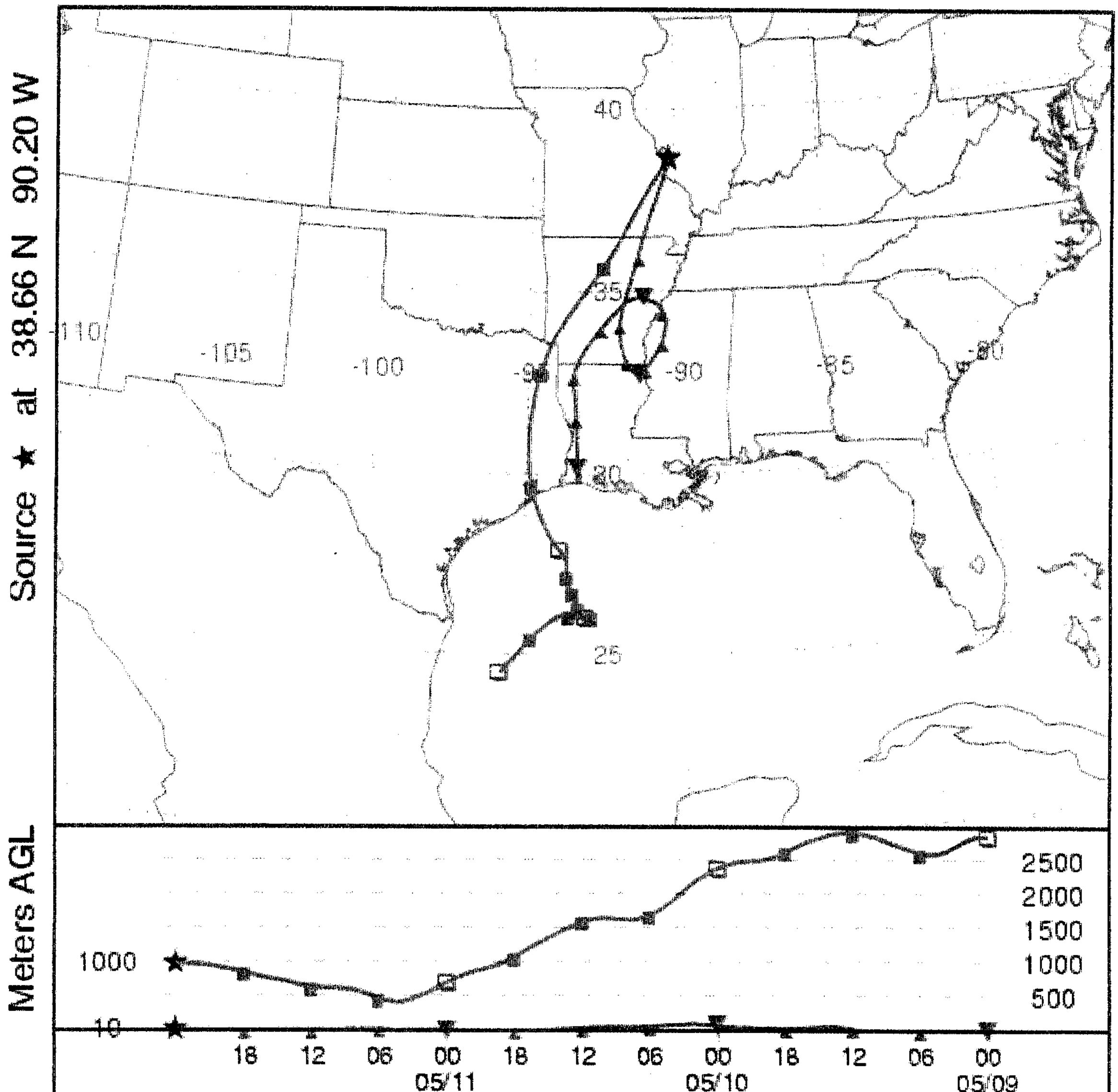
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 31 Mar 00
EDAS Meteorological Data



NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 30 Apr 00
EDAS Meteorological Data

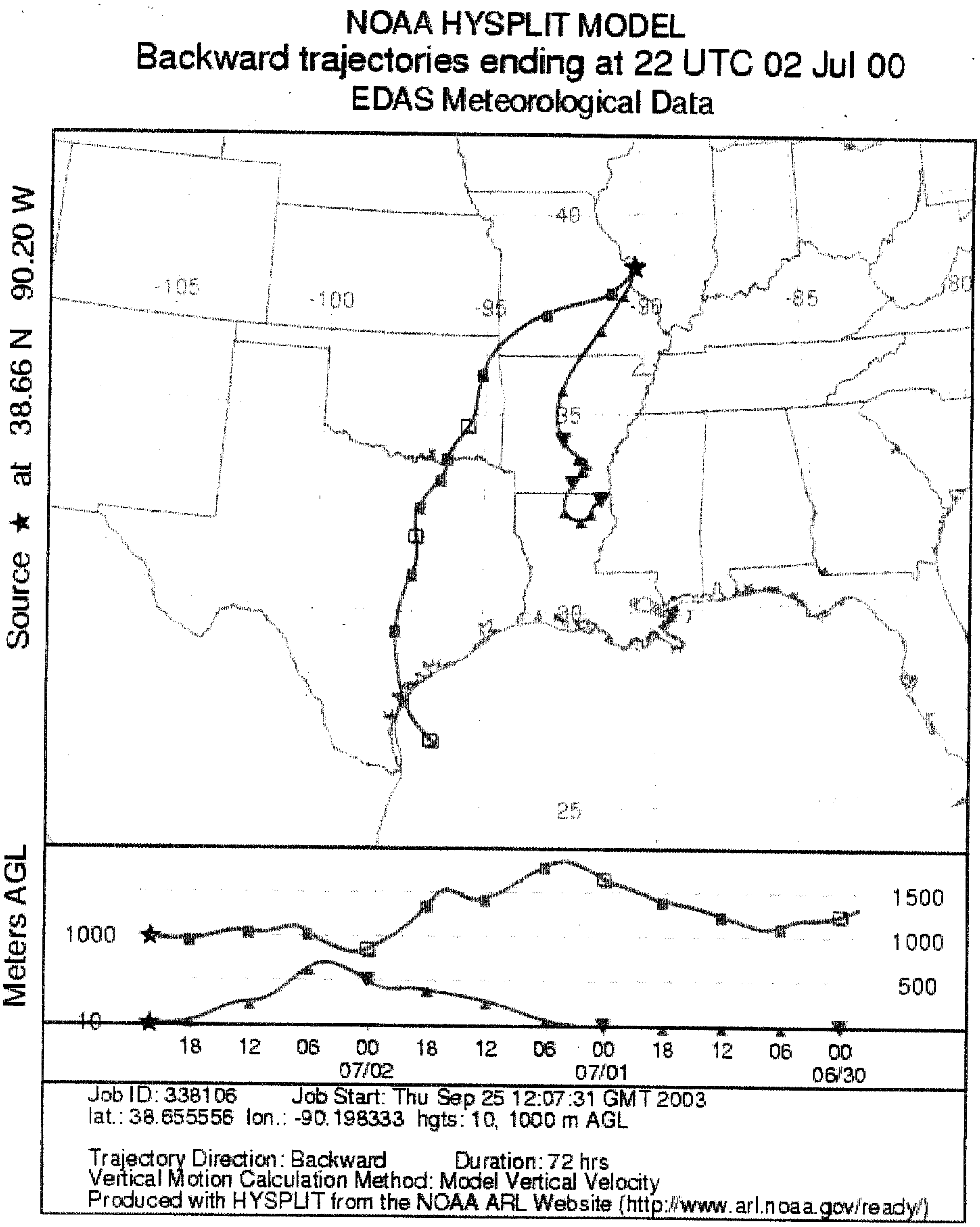


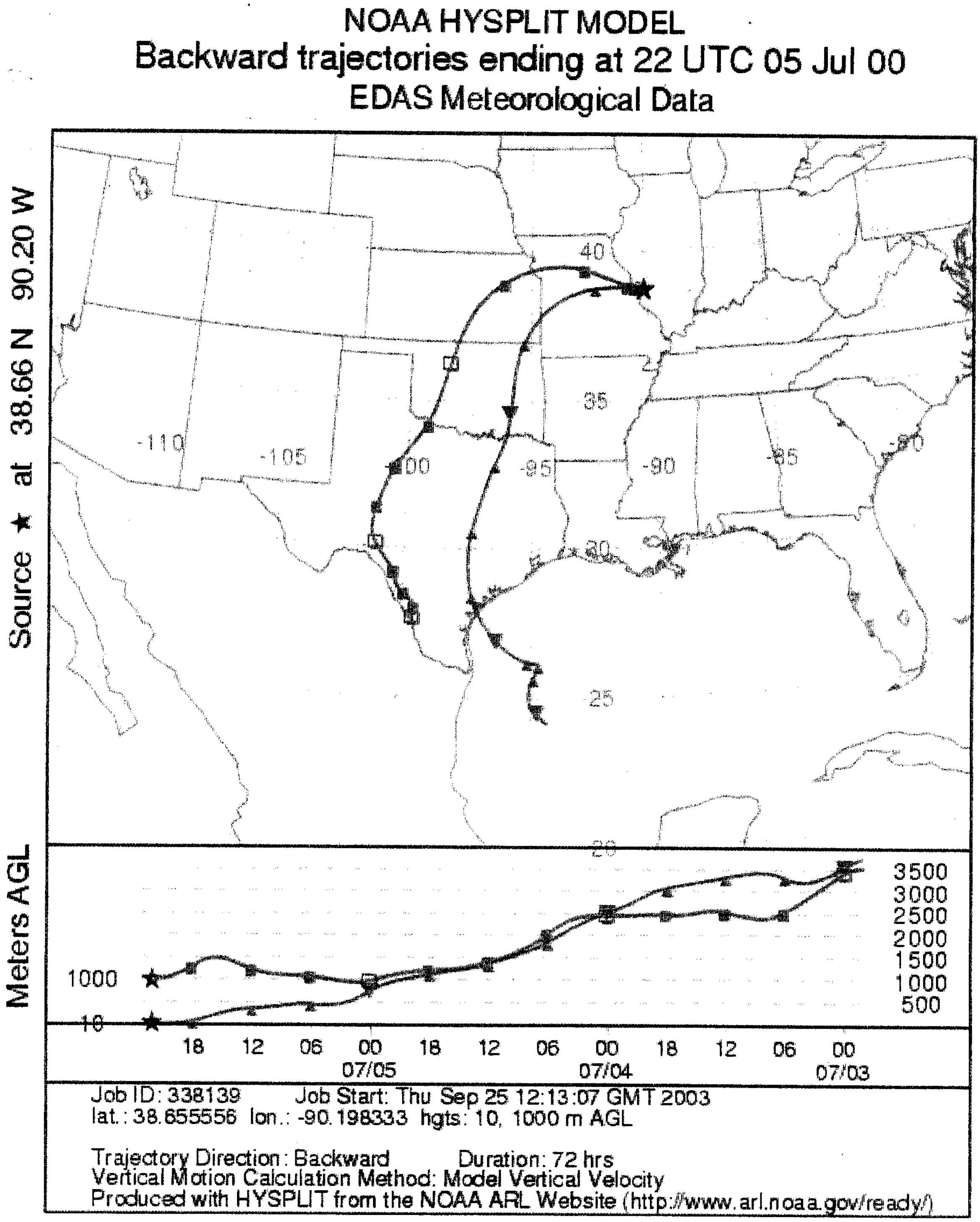
NOAA HYSPLIT MODEL
Backward trajectories ending at 00 UTC 12 May 00
EDAS Meteorological Data

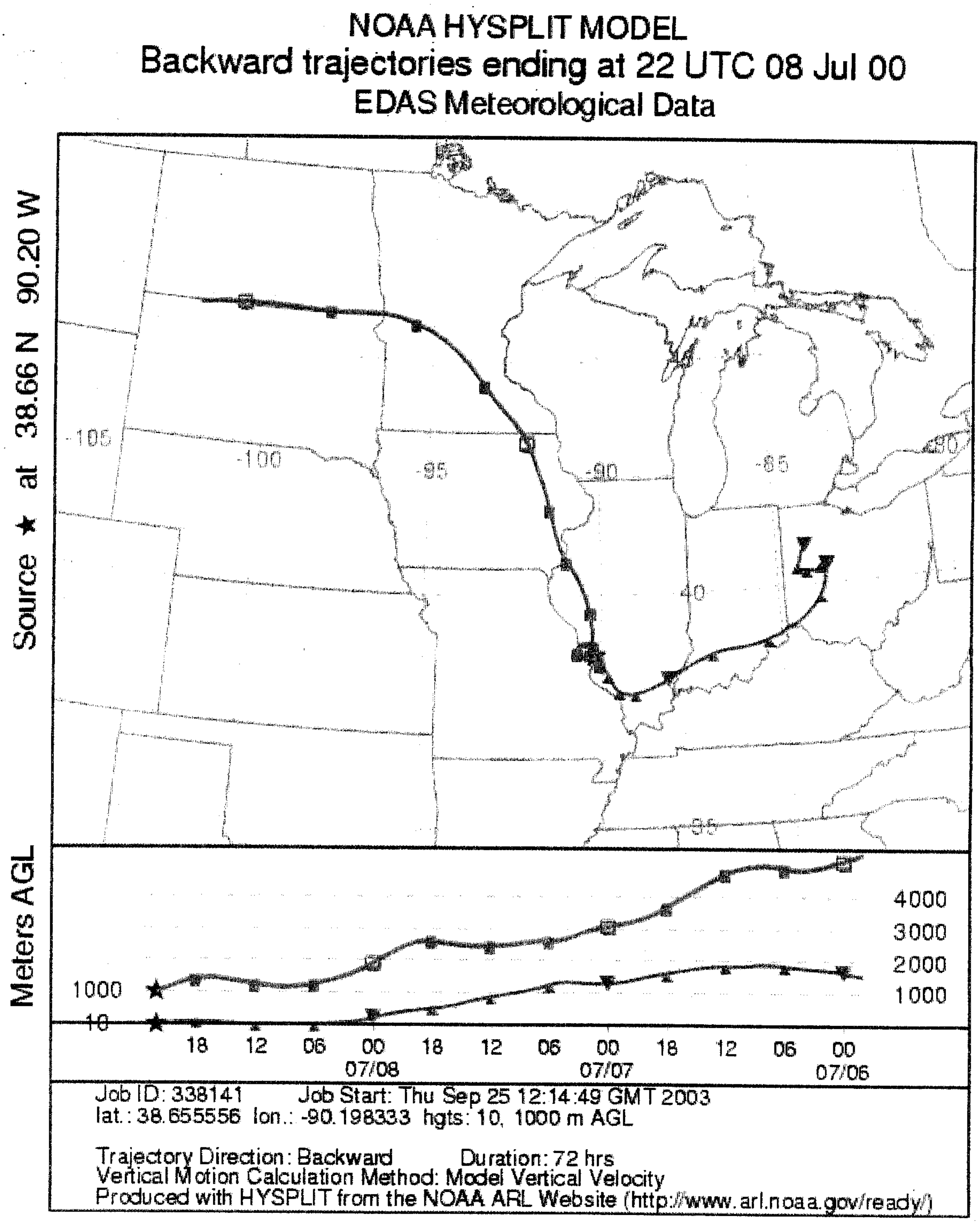


Job ID: 335415 Job Start: Wed Sep 24 22:23:51 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

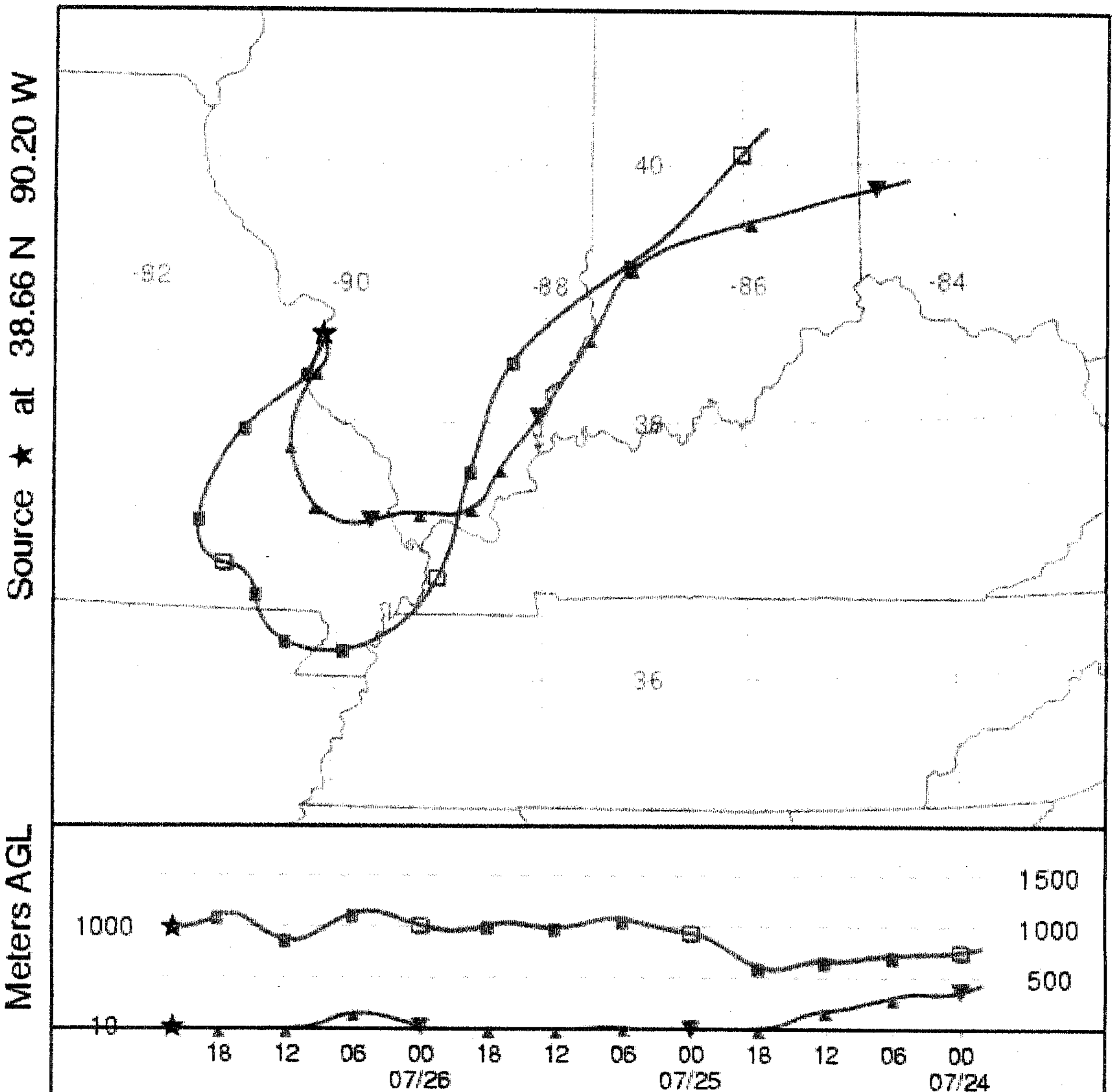
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 02 Jul 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-105
-100
-95
-90
-85
-80
40
35
30
25
Meters AGL
1000
10
1500
1000
500
18 12 06 00 18 12 06 00 18 12 06 00
07/02
07/01
06/30
Job ID: 338106 Job Start: Thu Sep 25 12:07:31 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 05 Jul 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
40
35
30
25
20
-110
-105
-100
-95
-90
-85
-80
Meters AGL
1000
10
3500
3000
2500
2000
1500
1000
500
18 12 06 00 18 12 06 00 18 12 06 00
07/05
07/04
07/03
Job ID: 338139 Job Start: Thu Sep 25 12:13:07 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 08 Jul 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-105
-100
-95
-90
-85
-80
40
35
Meters AGL
4000
3000
2000
1000
1000
10
18
12
06
00
07/08
18
12
06
00
07/07
18
12
06
00
07/06
Job ID: 338141 Job Start: Thu Sep 25 12:14:49 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

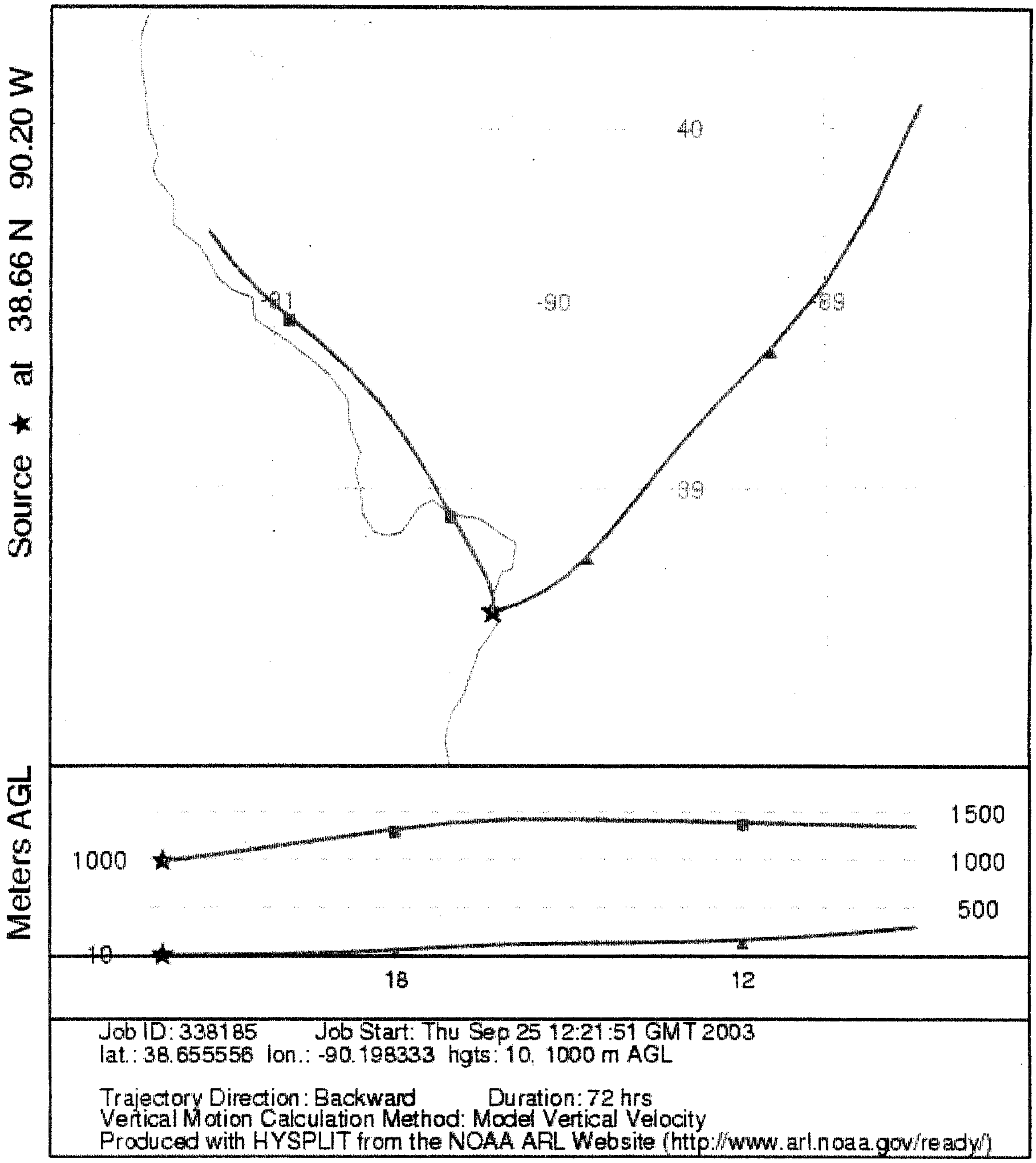
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 26 Jul 00
EDAS Meteorological Data

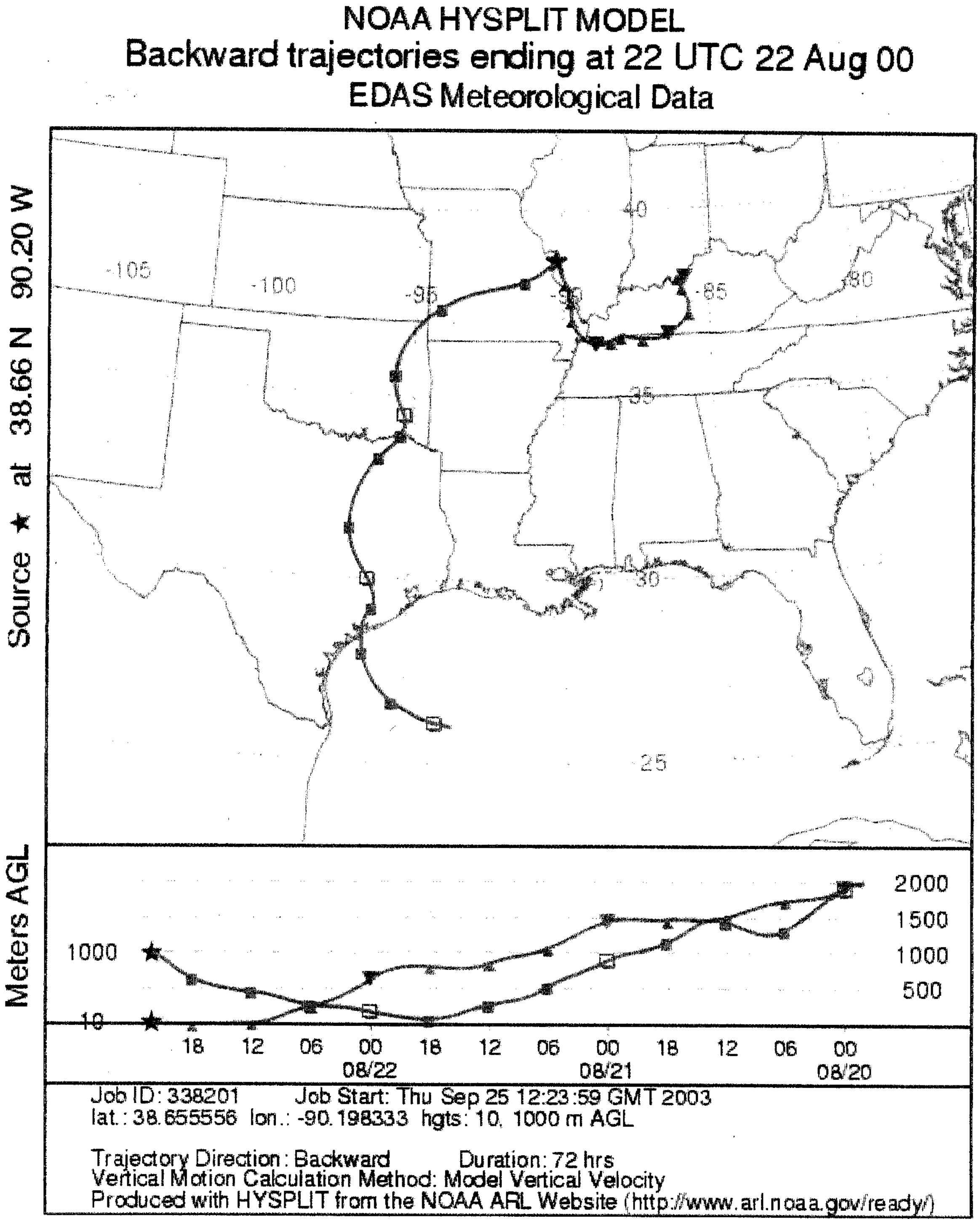


Job ID: 338160 Job Start: Thu Sep 25 12:18:18 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

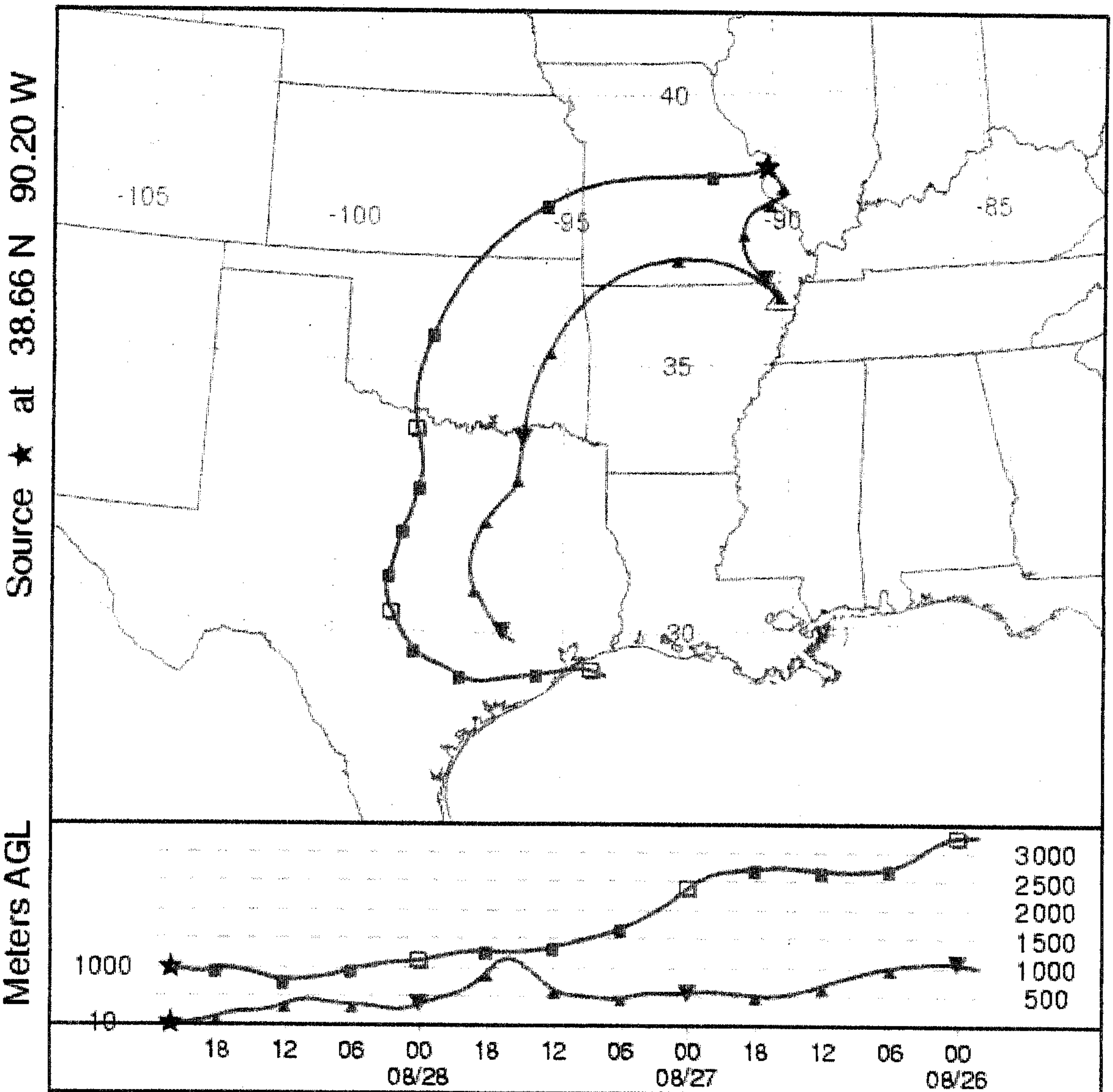
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 16 Aug 00
EDAS Meteorological Data




NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 22 Aug 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-105
-100
-95
-90
-85
-80
40
35
30
25
Meters AGL
1000
10
2000
1500
1000
500
18 12 06 00 18 12 06 00 18 12 06 00
08/22
08/21
08/20
Job ID: 338201 Job Start: Thu Sep 25 12:23:59 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

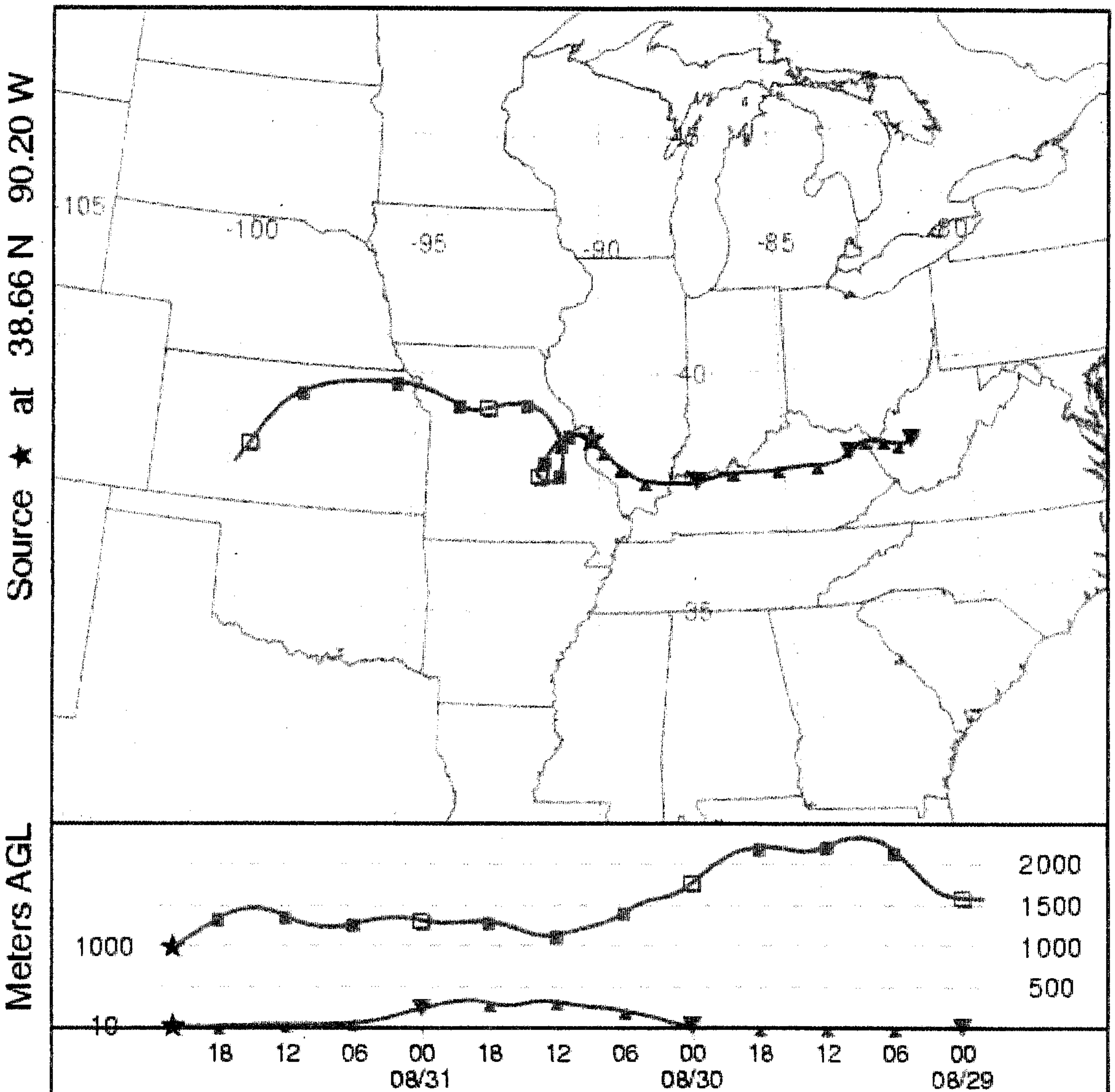
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 28 Aug 00
EDAS Meteorological Data



Job ID: 338232 Job Start: Thu Sep 25 12:30:31 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

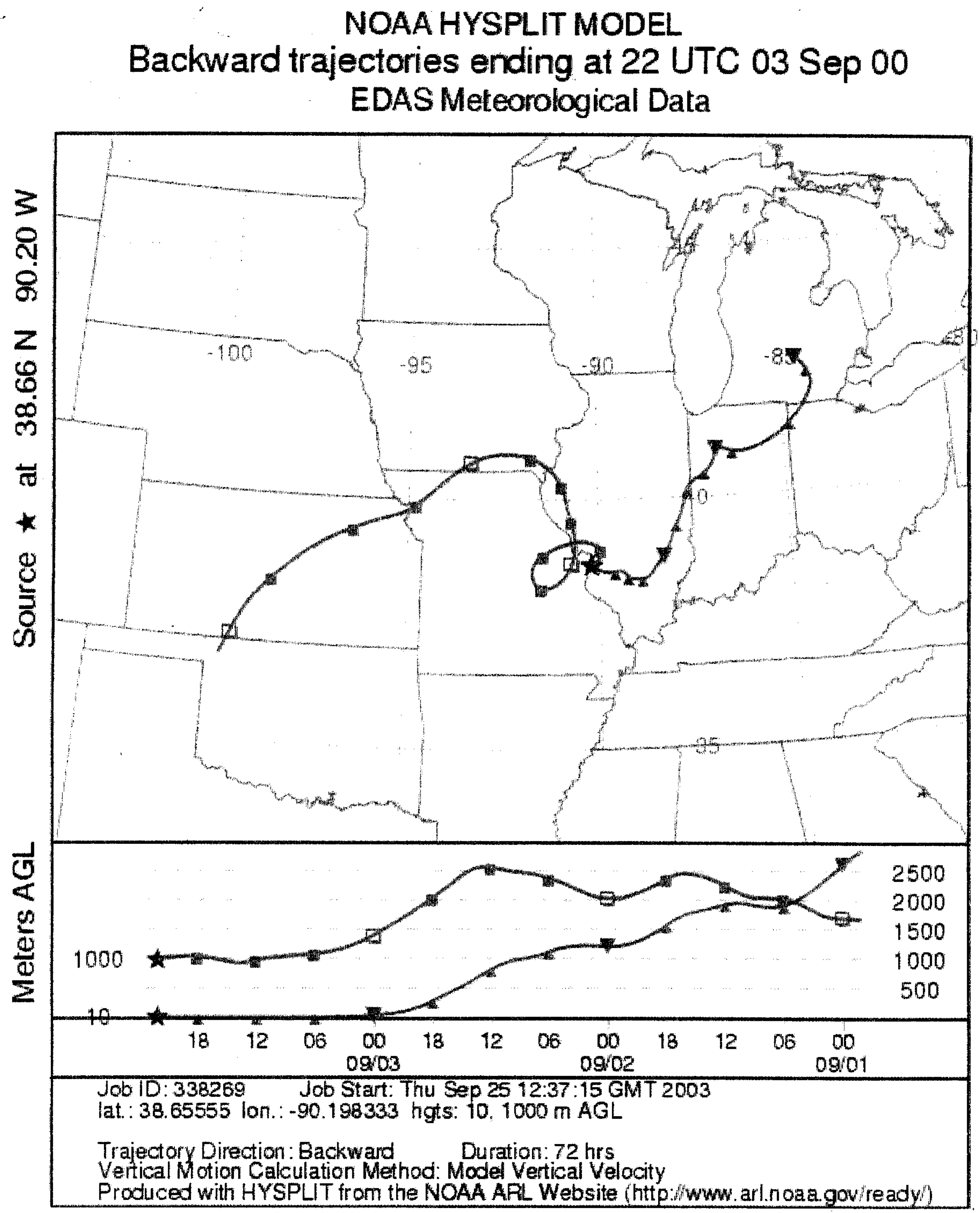
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 31 Aug 00
EDAS Meteorological Data

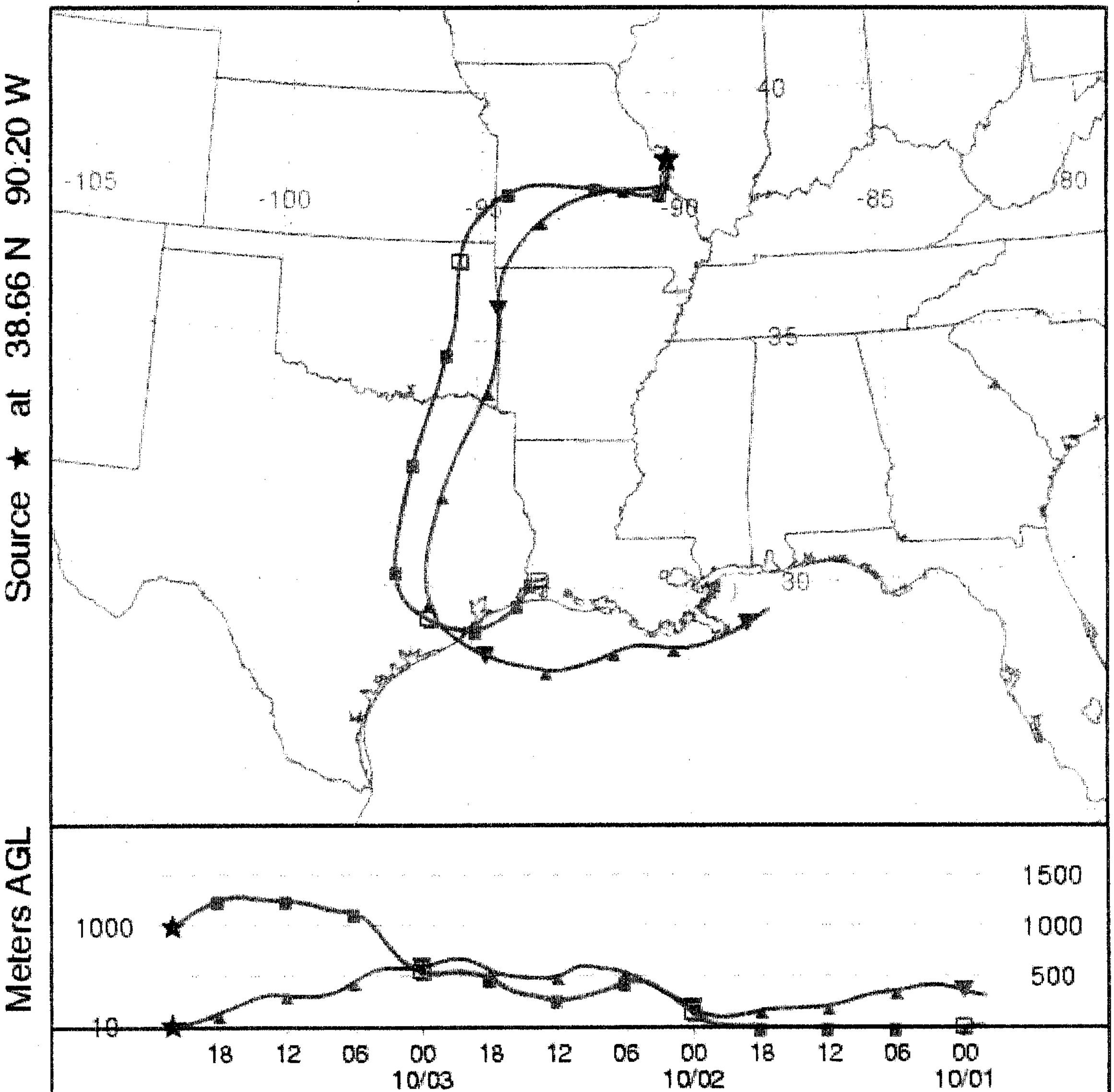


Job ID: 338247 Job Start: Thu Sep 25 12:32:56 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 03 Sep 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-100
-95
-90
-85
-80
35
Meters AGL
1000
10
2500
2000
1500
1000
500
18
12
06
00
09/03
18
12
06
00
09/02
18
12
06
00
09/01
Job ID: 338269 Job Start: Thu Sep 25 12:37:15 GMT 2003
lat.: 38.65555 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

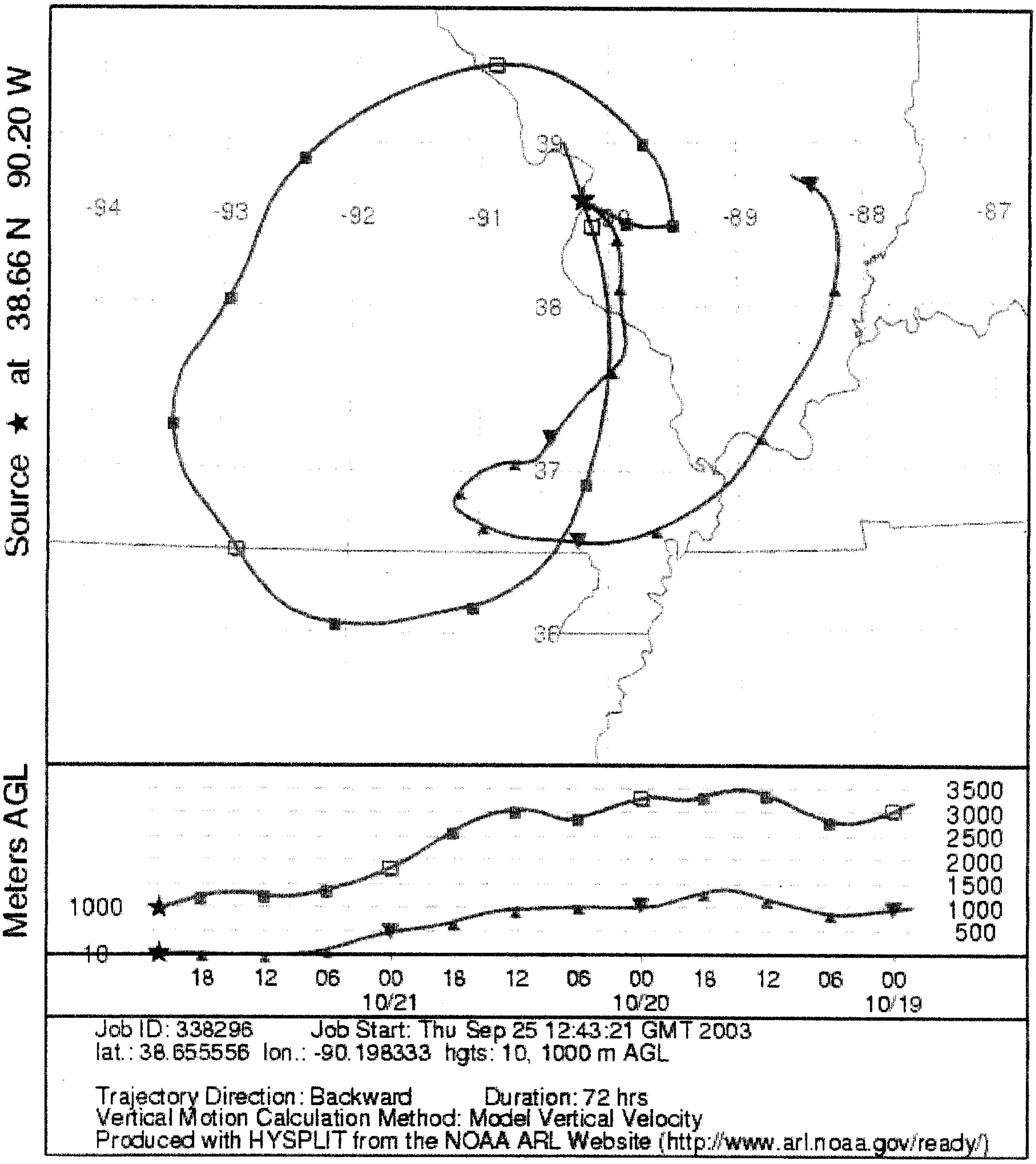
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 03 Oct 00
EDAS Meteorological Data



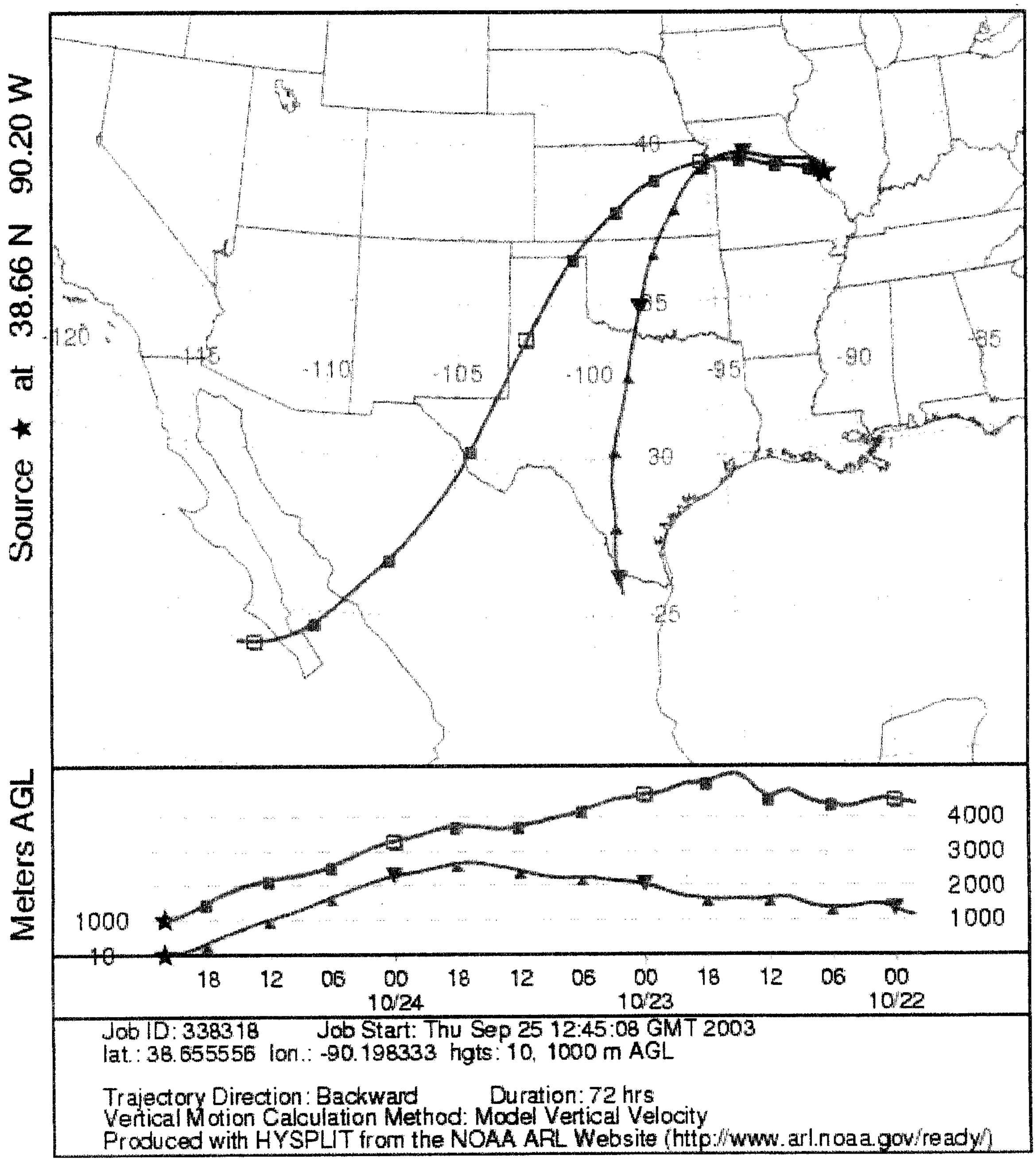
Job ID: 338271 Job Start: Thu Sep 25 12:40:52 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

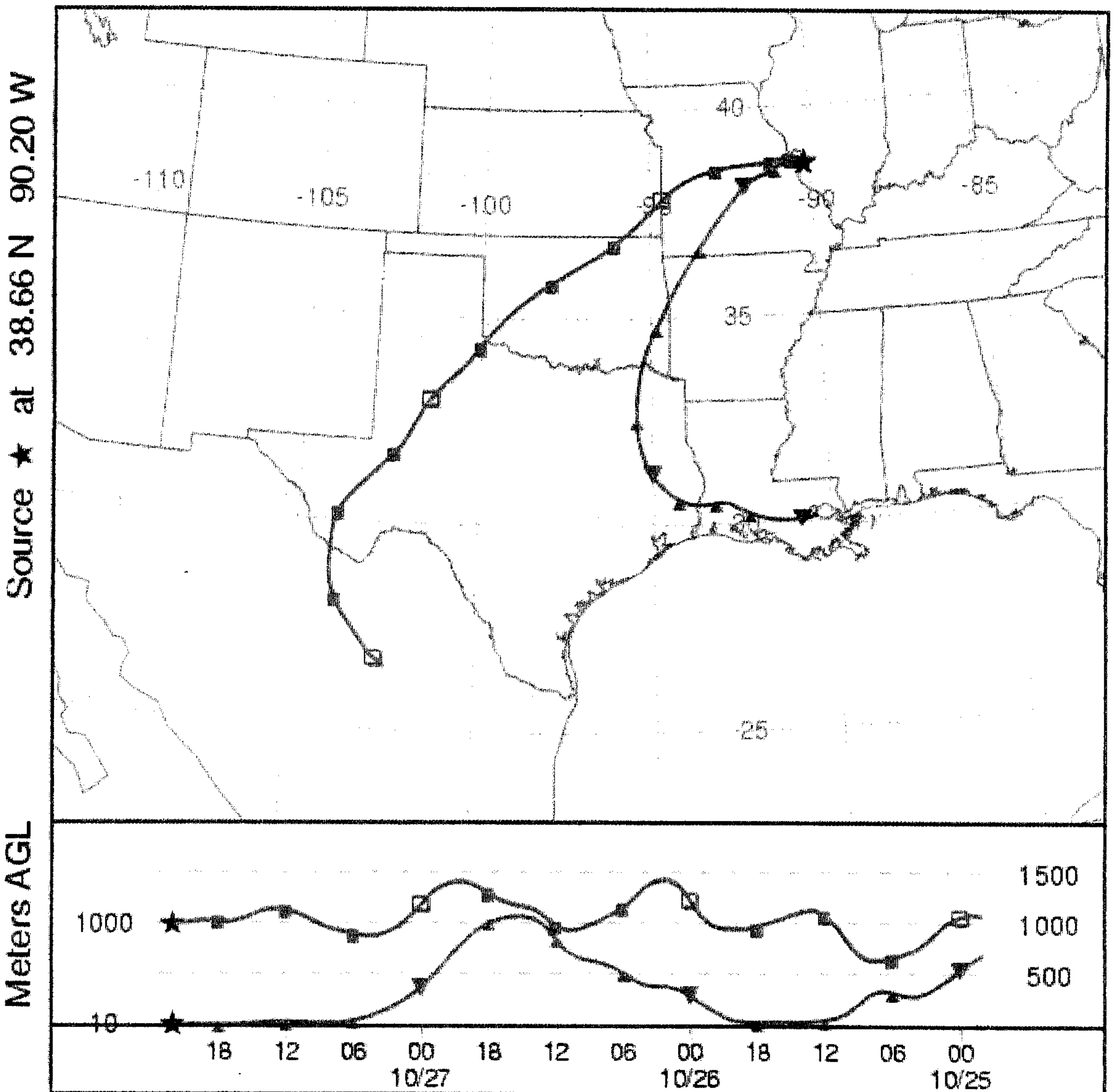
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 21 Oct 00
EDAS Meteorological Data



NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 24 Oct 00
EDAS Meteorological Data



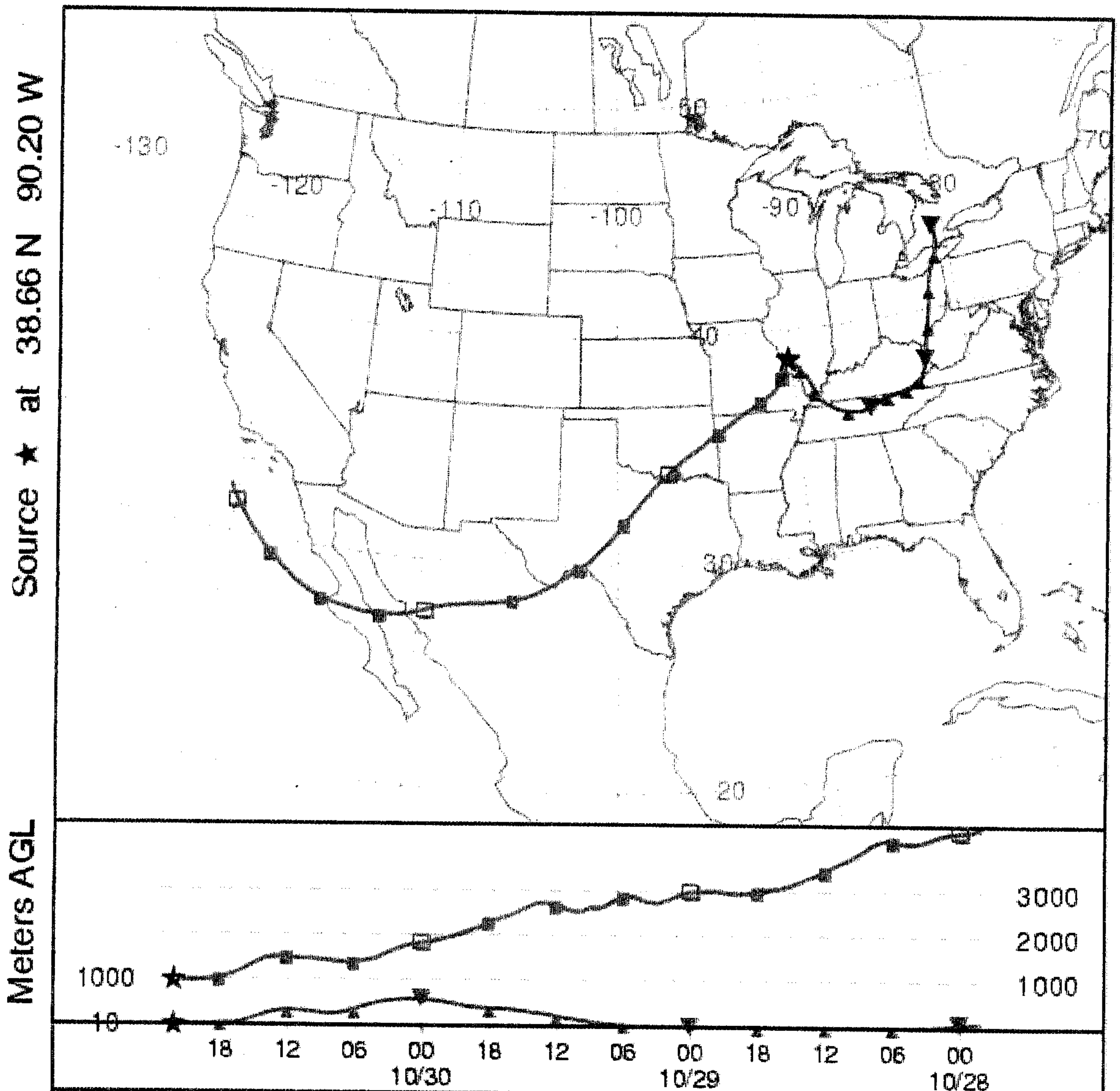
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 27 Oct 00
EDAS Meteorological Data



Job ID: 338335 Job Start: Thu Sep 25 12:46:54 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

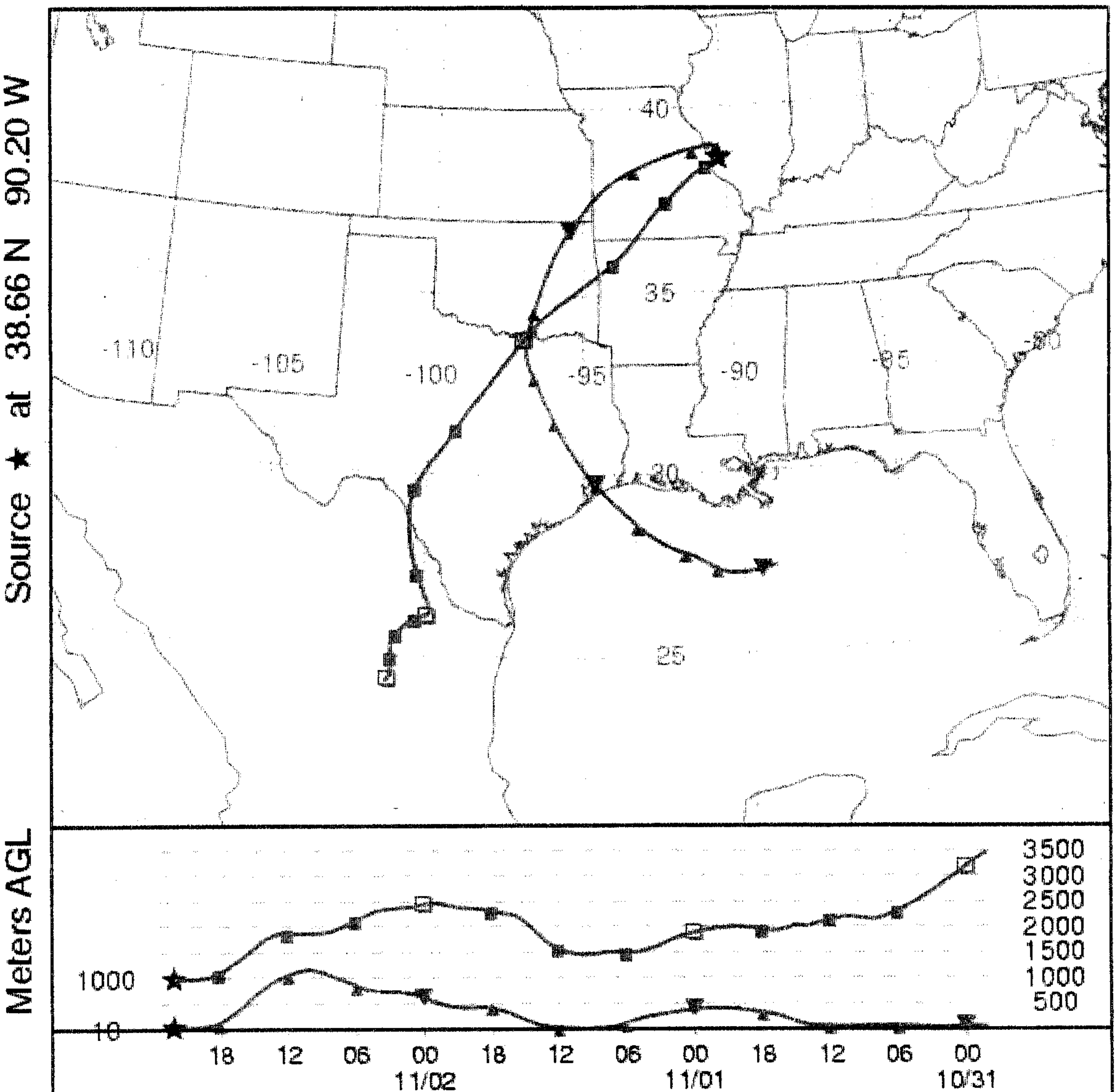
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 30 Oct 00
EDAS Meteorological Data



Job ID: 338389 Job Start: Thu Sep 25 12:51:06 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

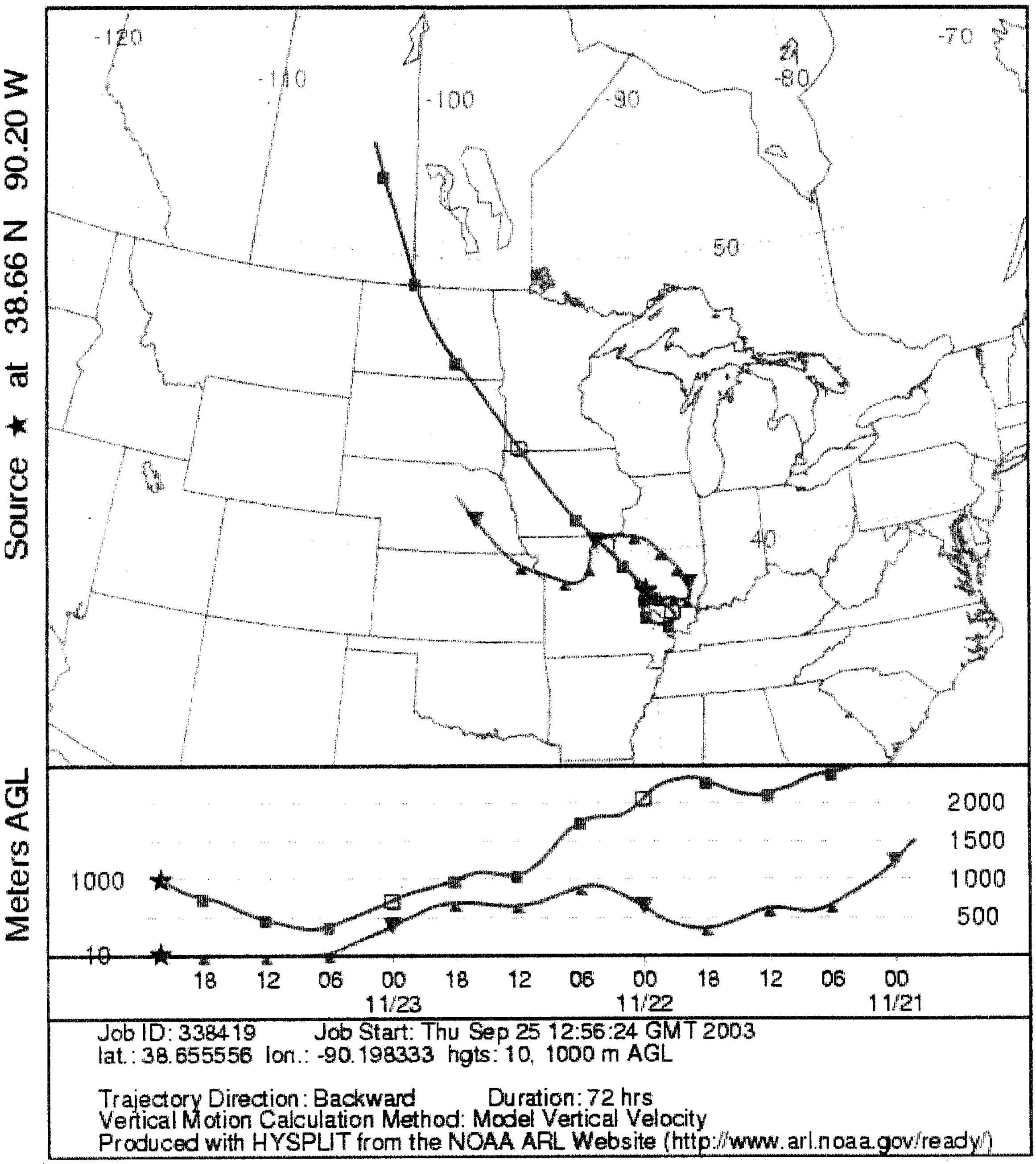
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 02 Nov 00
EDAS Meteorological Data

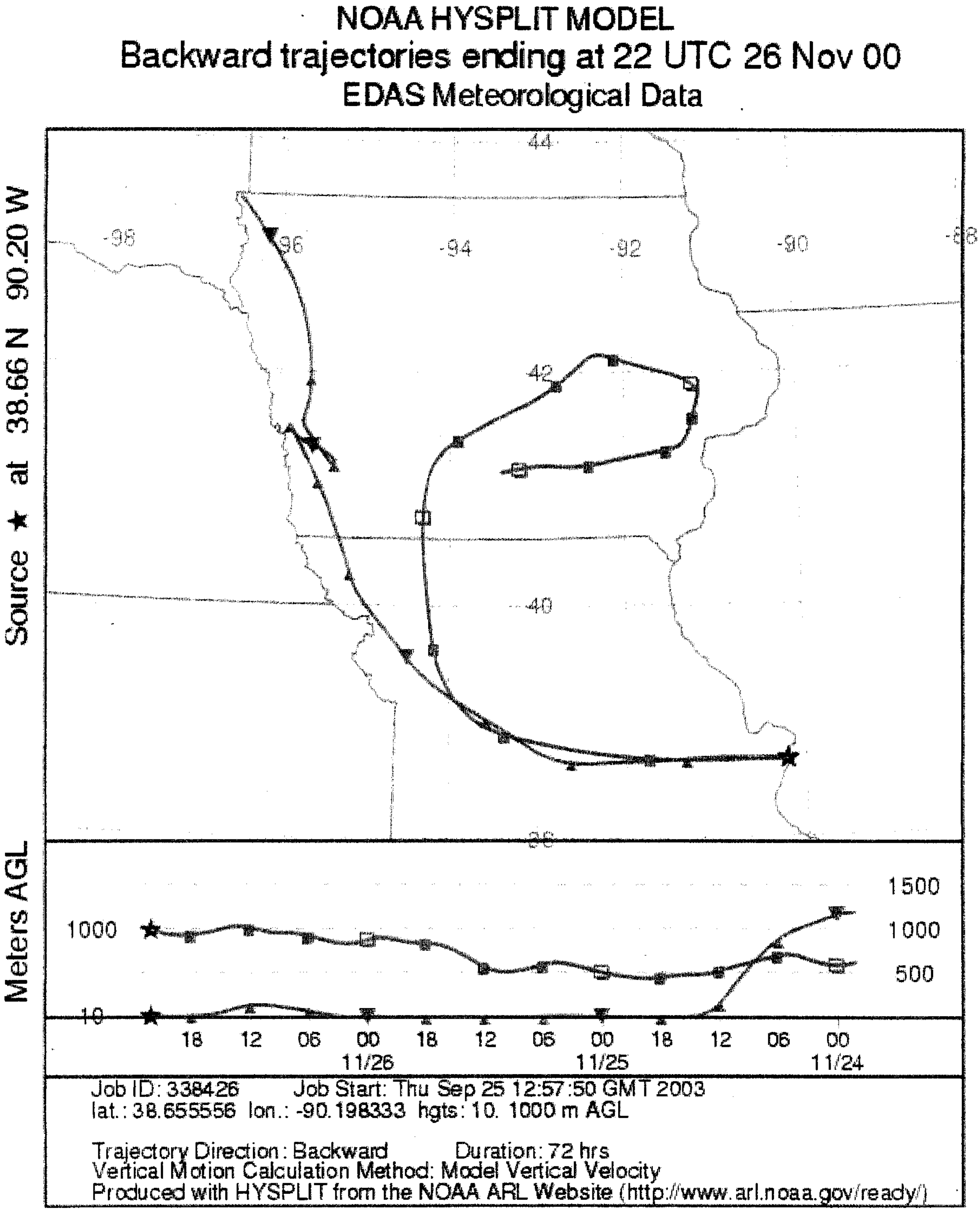


Job ID: 338390 Job Start: Thu Sep 25 12:53:44 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

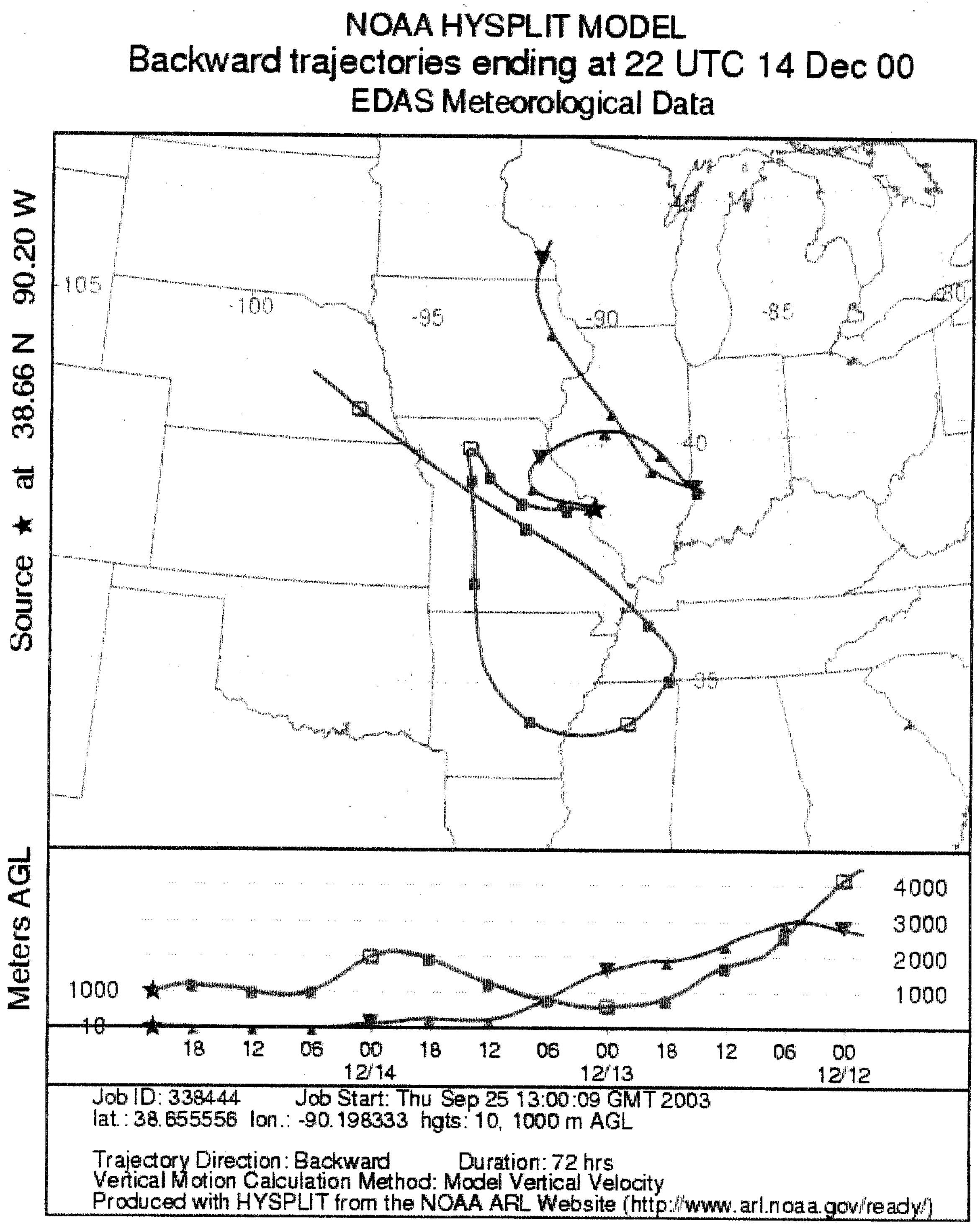
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 23 Nov 00
EDAS Meteorological Data



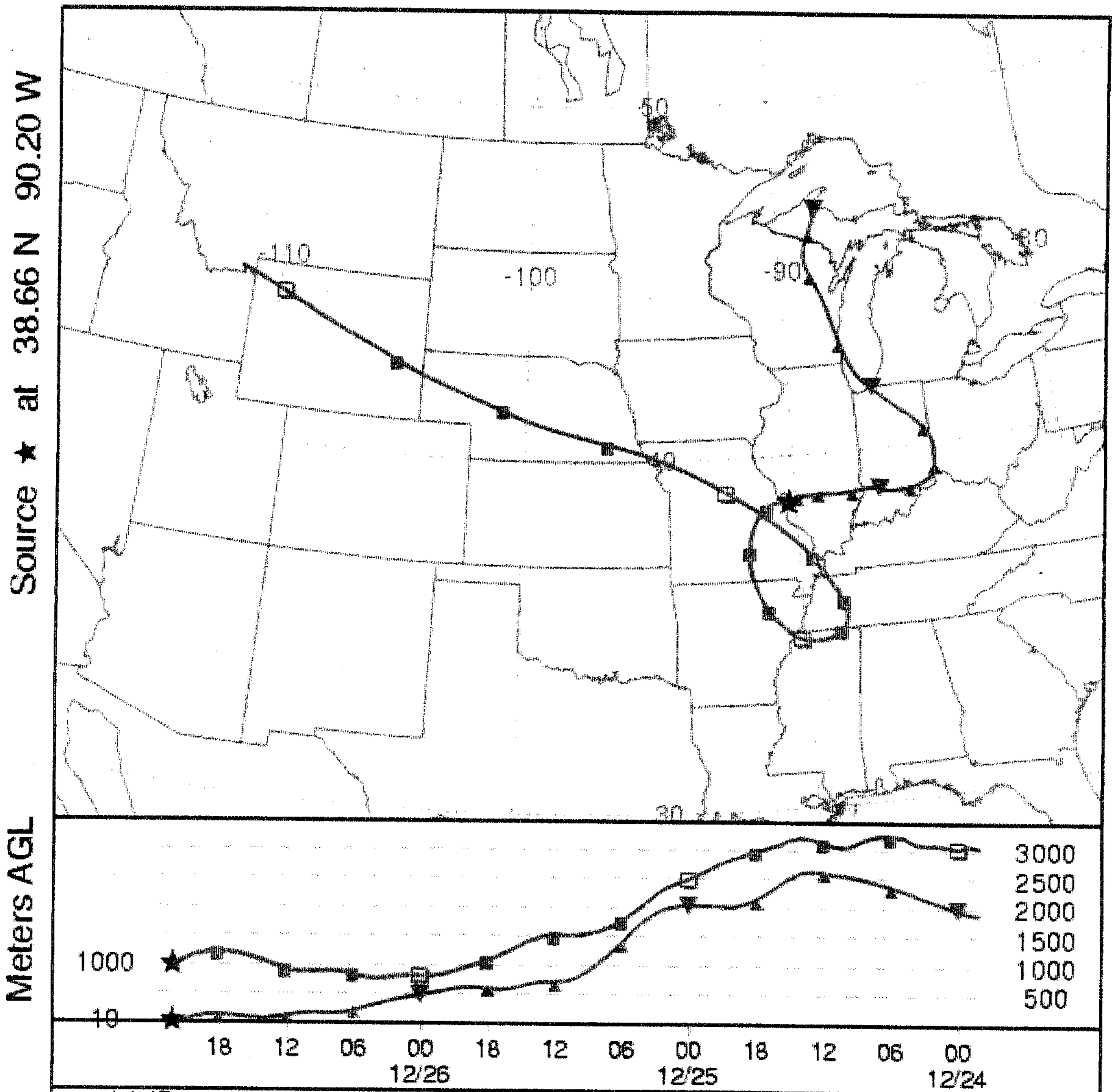


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 26 Nov 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
Meters AGL
44
42
40
-96
-94
-92
-90
-88
1500
1000
500
10
18 12 06 00 18 12 06 00 18 12 06 00
11/26
11/25
11/24
Job ID: 338426 Job Start: Thu Sep 25 12:57:50 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10. 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)



NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 14 Dec 00
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-105
-100
-95
-90
-85
-80
40
35
Meters AGL
1000
10
4000
3000
2000
1000
18 12 06 00 18 12 06 00 18 12 06 00
12/14
12/13
12/12
Job ID: 338444 Job Start: Thu Sep 25 13:00:09 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

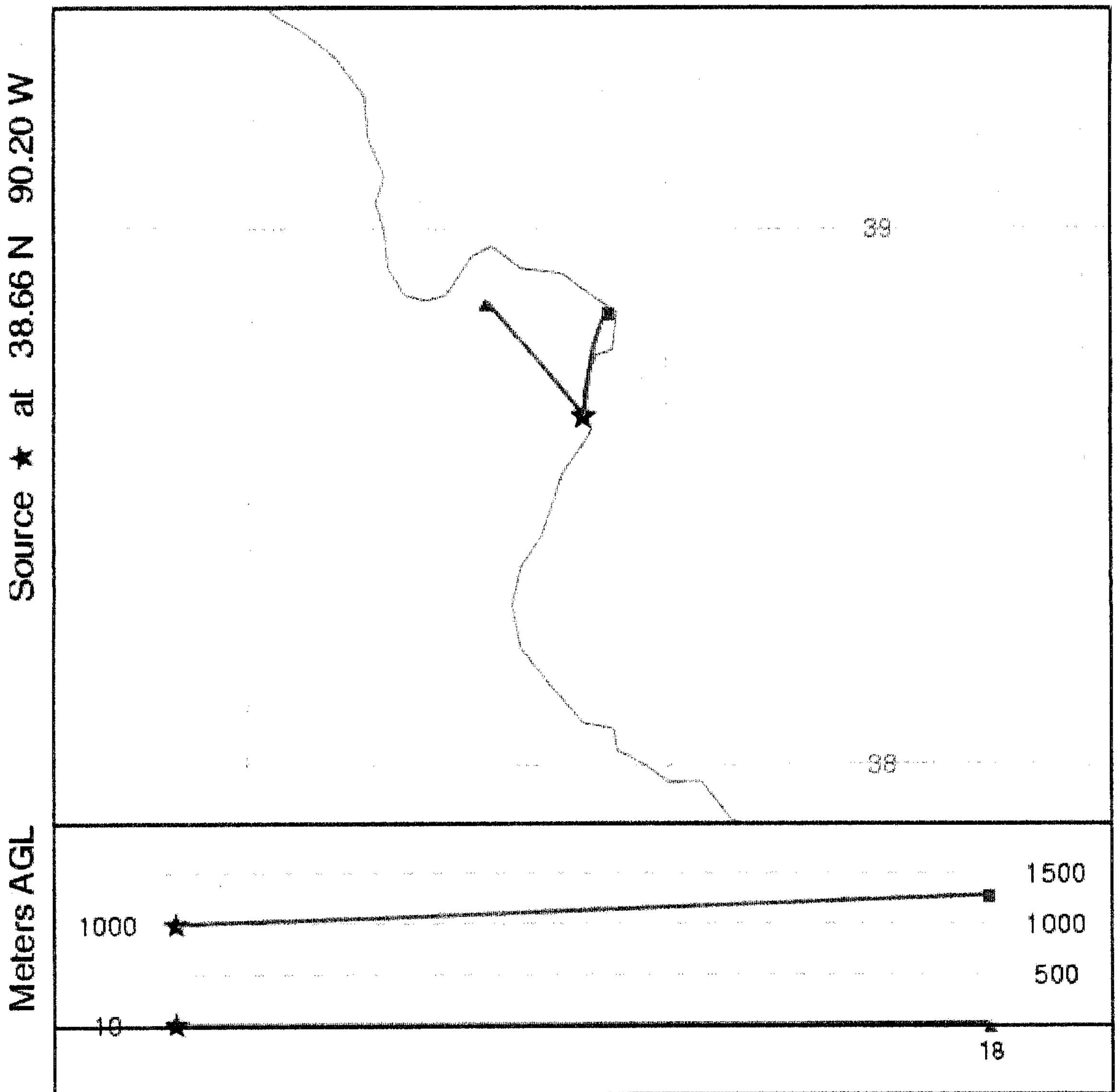
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 26 Dec 00
EDAS Meteorological Data



Job ID: 338464 Job Start: Thu Sep 25 13:04:38 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

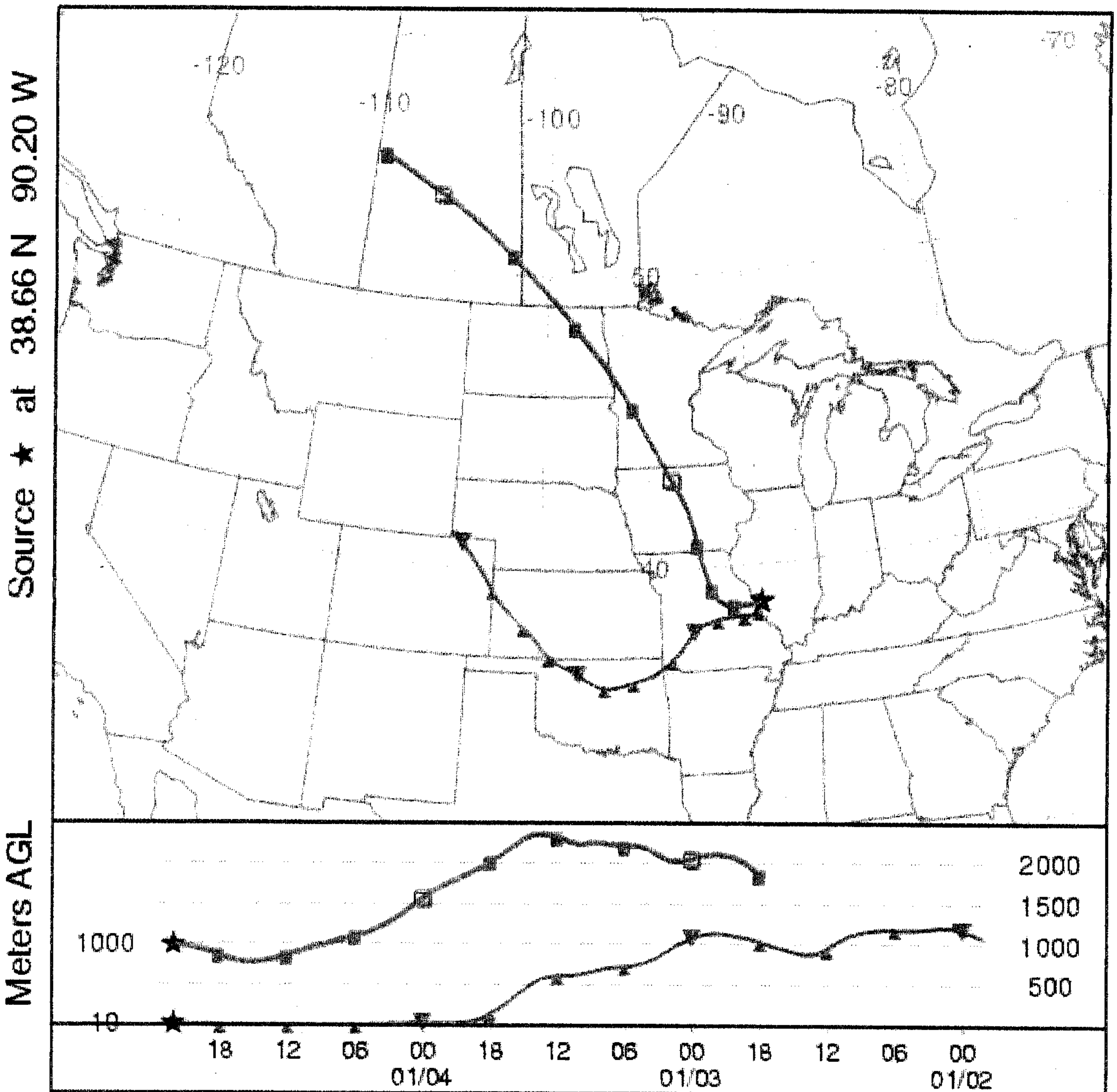
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 01 Jan 01
EDAS Meteorological Data



Job ID: 338529 Job Start: Thu Sep 25 13:21:00 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

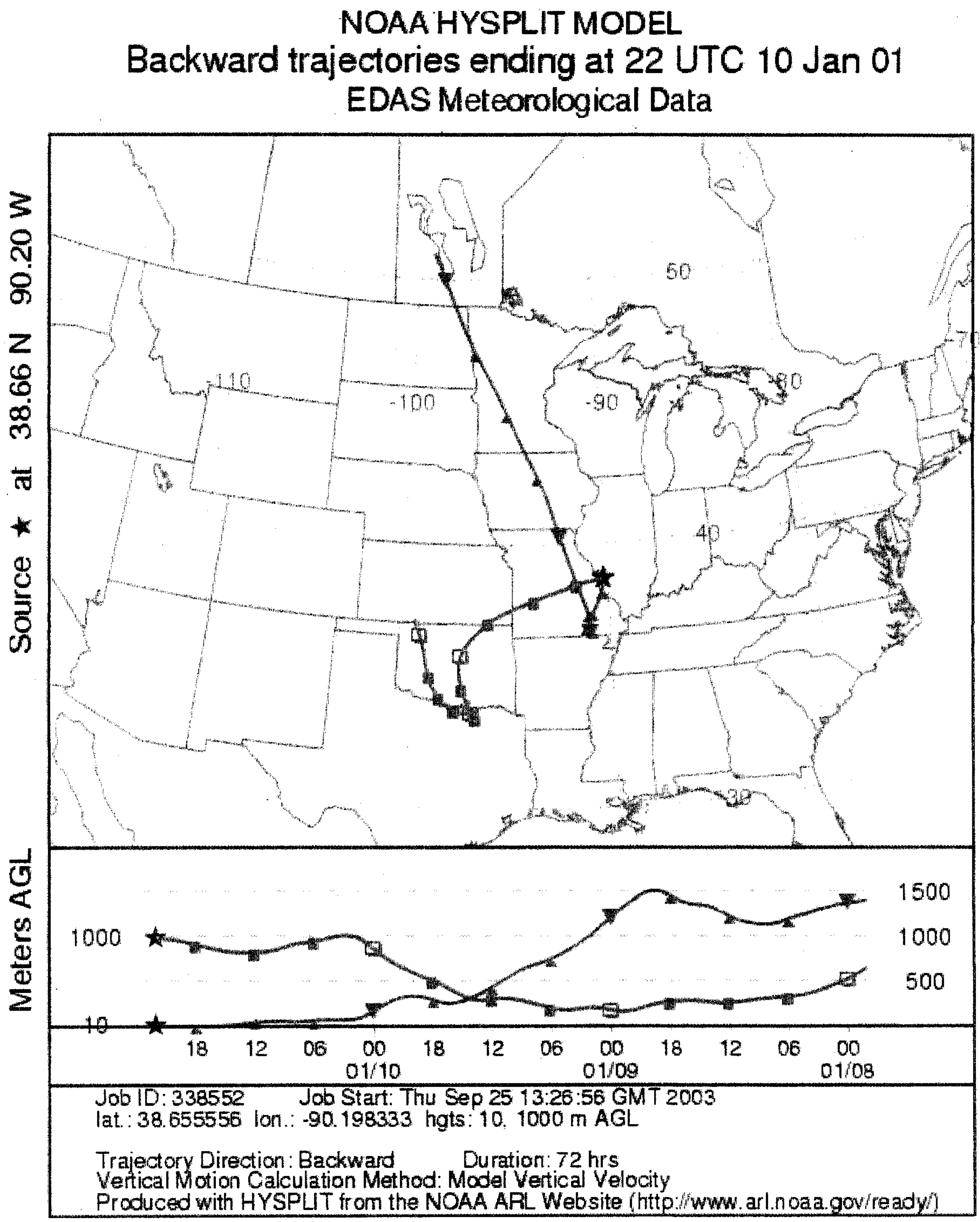
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 04 Jan 01
EDAS Meteorological Data



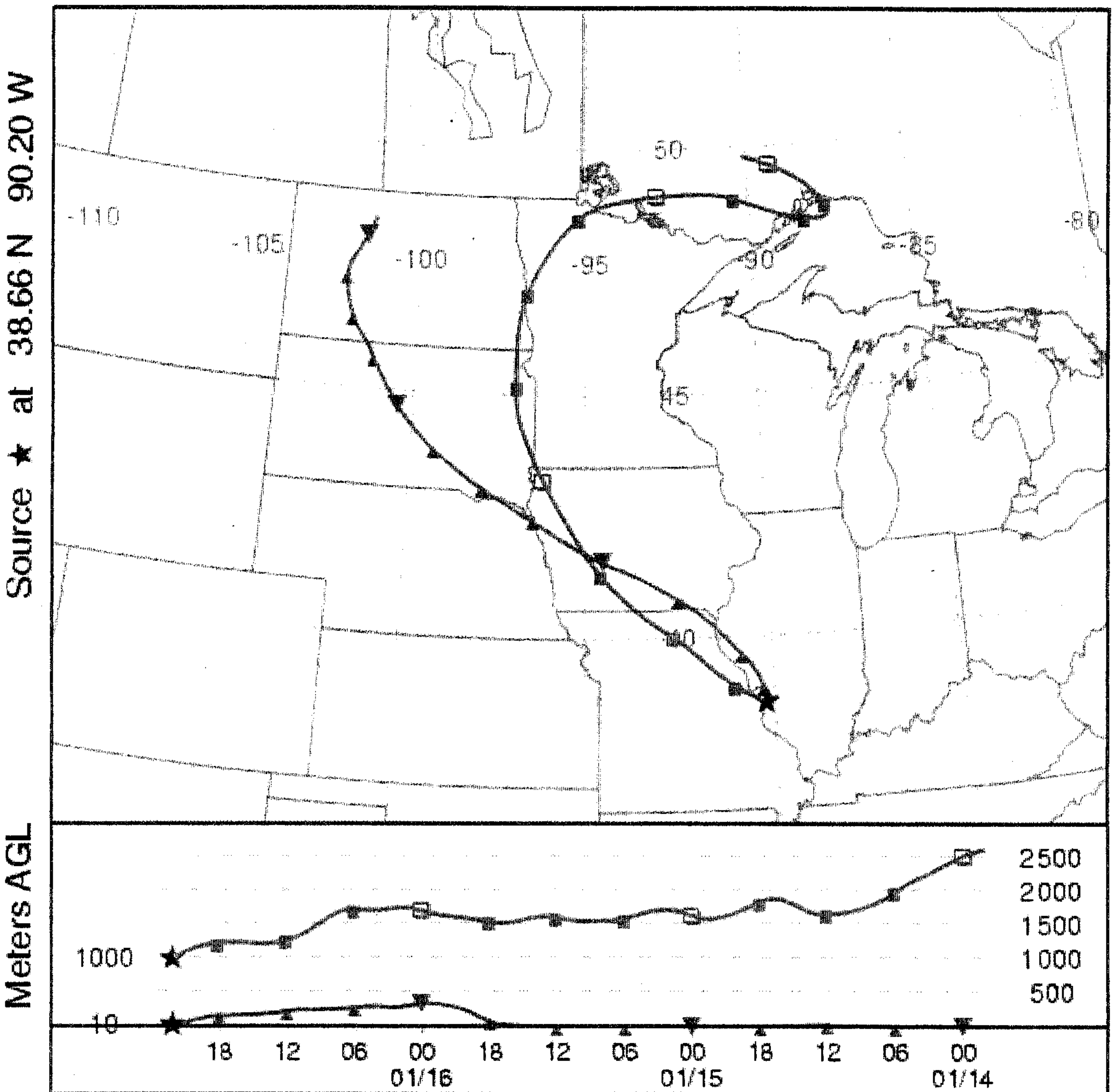
Job ID: 338549 Job Start: Thu Sep 25 13:24:53 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)



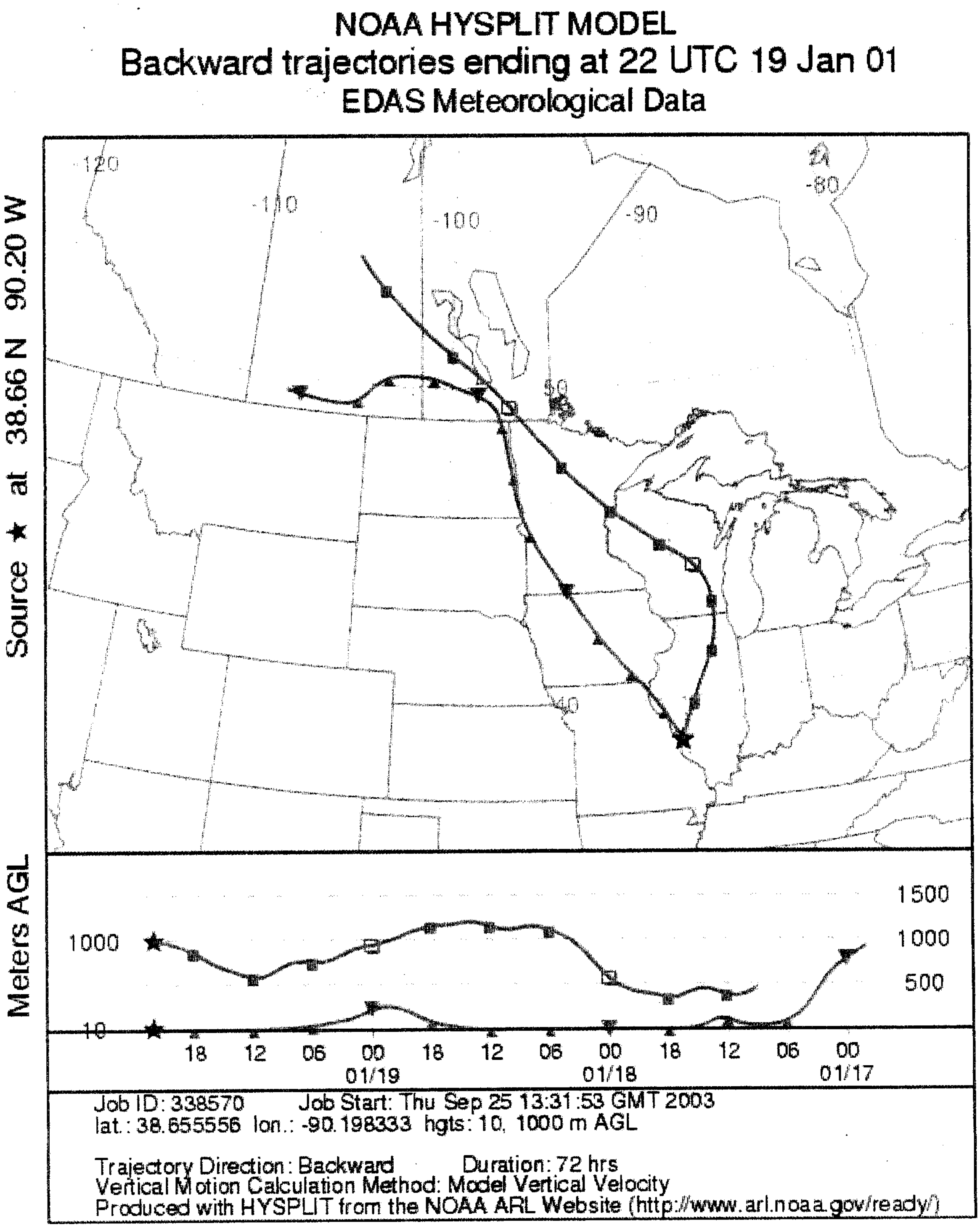
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 10 Jan 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
Meters AGL
50
-110
-100
-90
80
40
30
1500
1000
500
10
18 12 06 00 18 12 06 00 18 12 06 00
01/10
01/09
01/08
Job ID: 338552 Job Start: Thu Sep 25 13:26:56 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 16 Jan 01
EDAS Meteorological Data

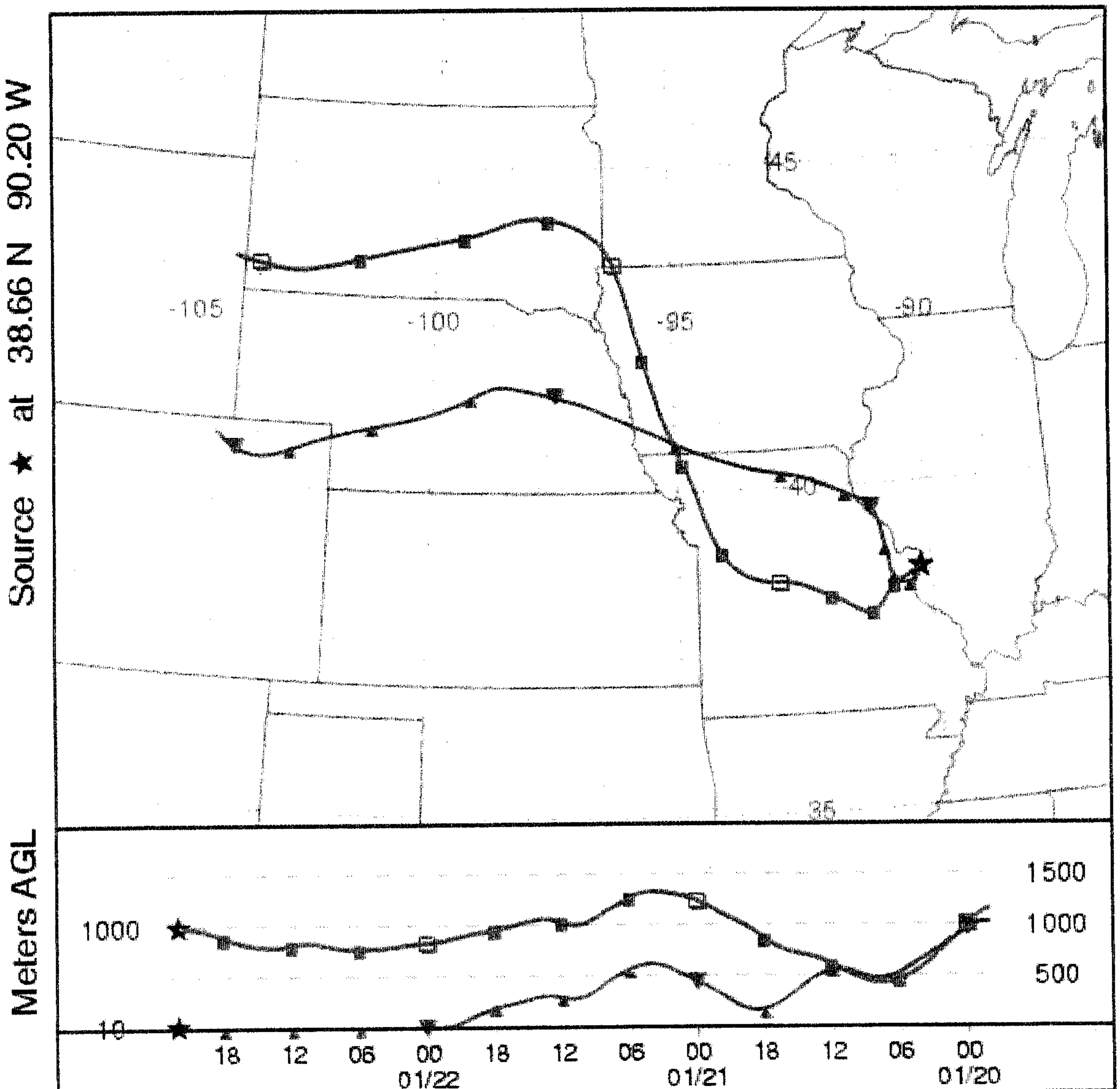


Job ID: 338561 Job Start: Thu Sep 25 13:30:19 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

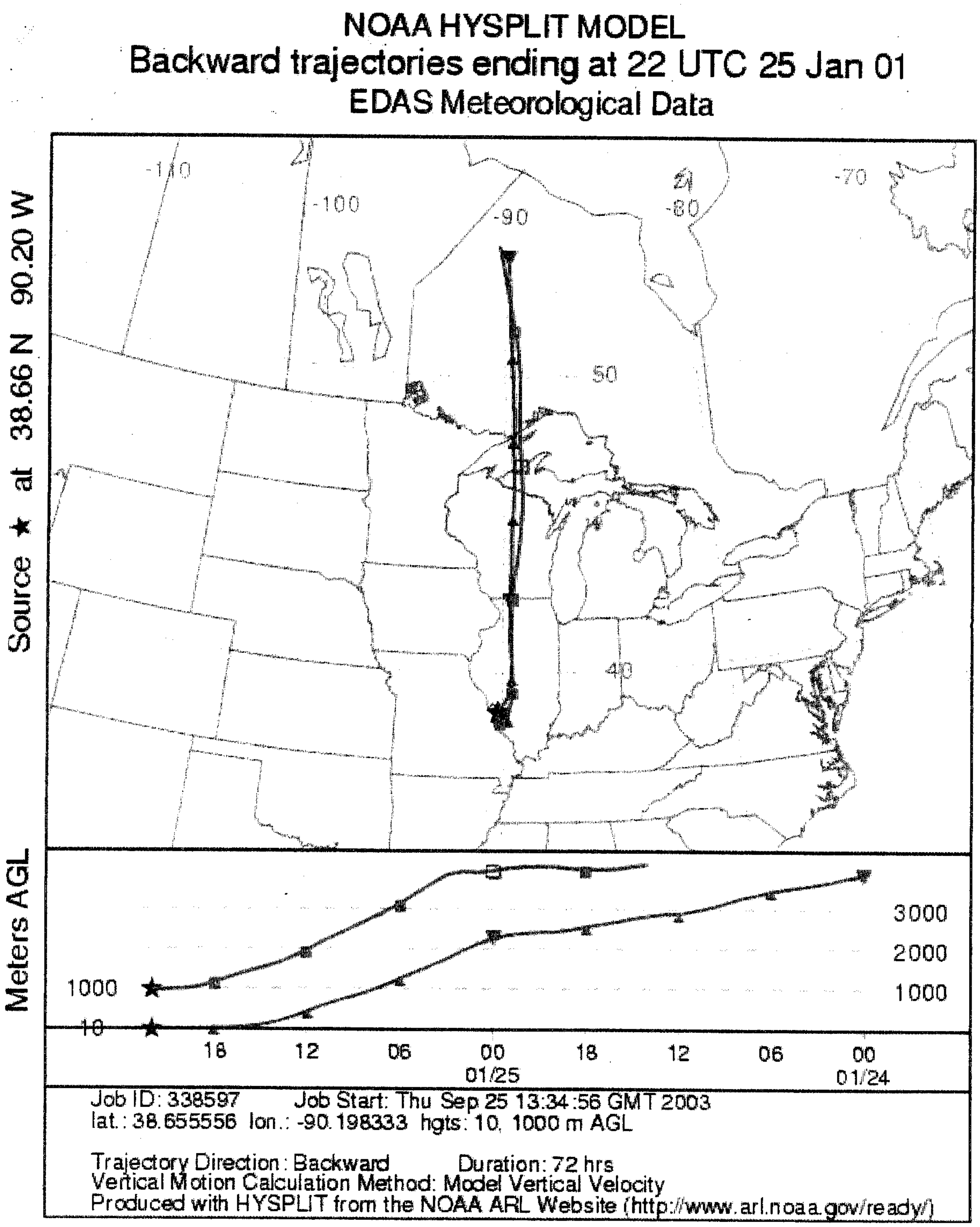

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 19 Jan 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-120
-110
-100
-90
-80
50
40
Meters AGL
1500
1000
500
10
18
12
06
00
01/19
01/18
01/17
Job ID: 338570 Job Start: Thu Sep 25 13:31:53 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 22 Jan 01
EDAS Meteorological Data

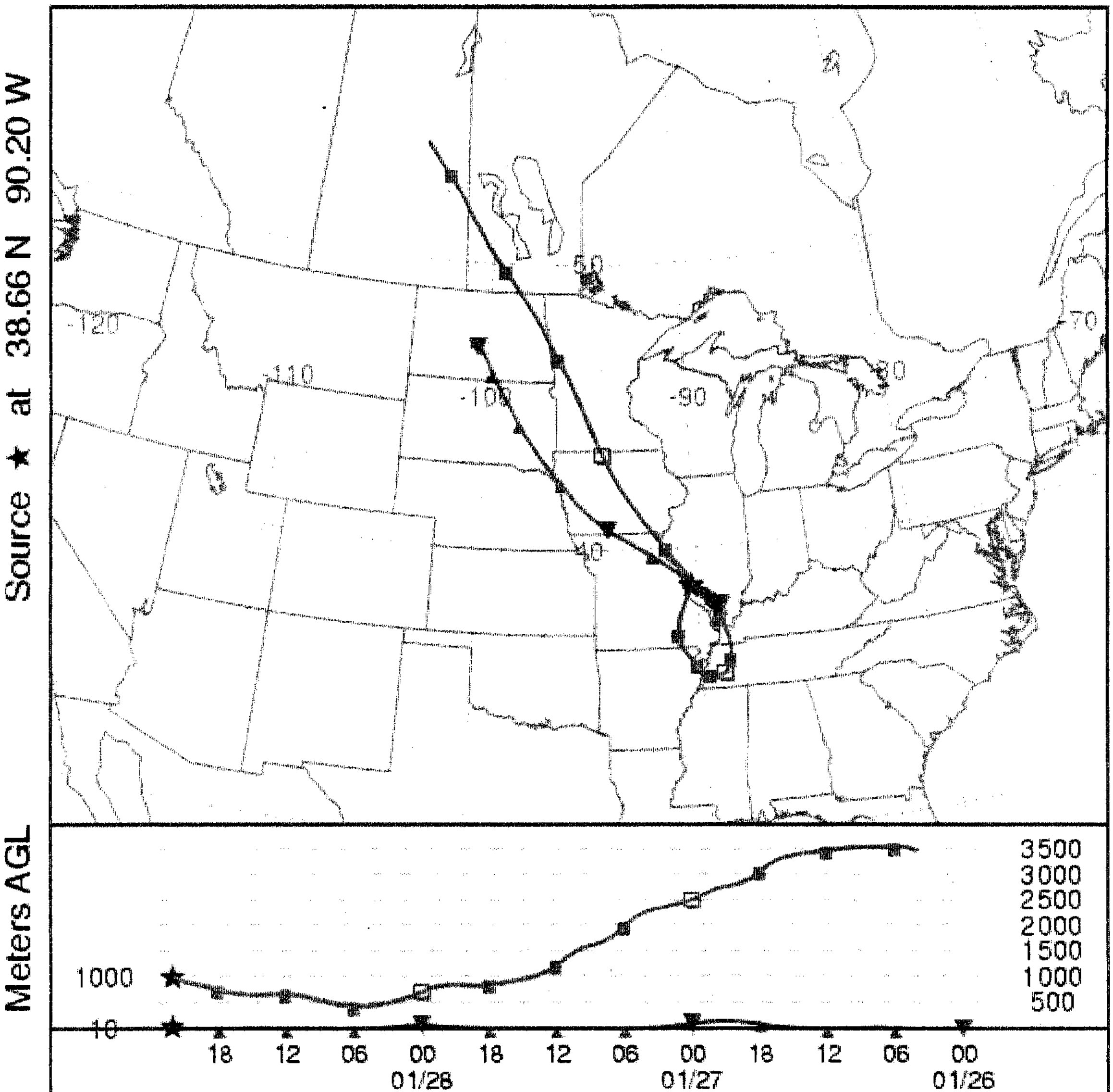


Job ID: 338588 Job Start: Thu Sep 25 13:33:17 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 25 Jan 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
Meters AGL
-110
-100
-90
-80
-70
50
40
3000
2000
1000
1000
10
18
12
06
00
01/25
18
12
06
00
01/24
Job ID: 338597 Job Start: Thu Sep 25 13:34:56 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

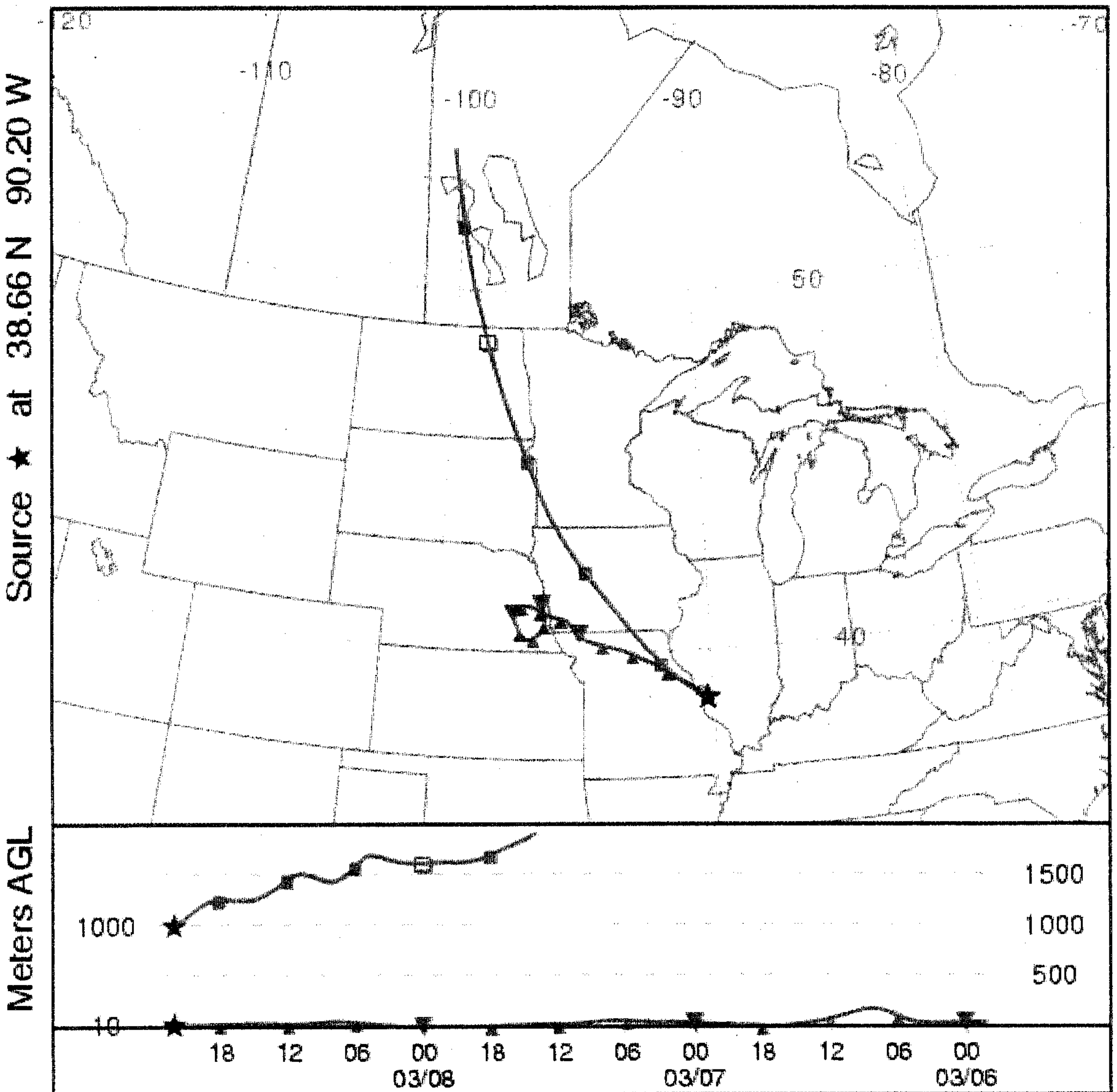
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 28 Jan 01
EDAS Meteorological Data



Job ID: 338605 Job Start: Thu Sep 25 13:36:48 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

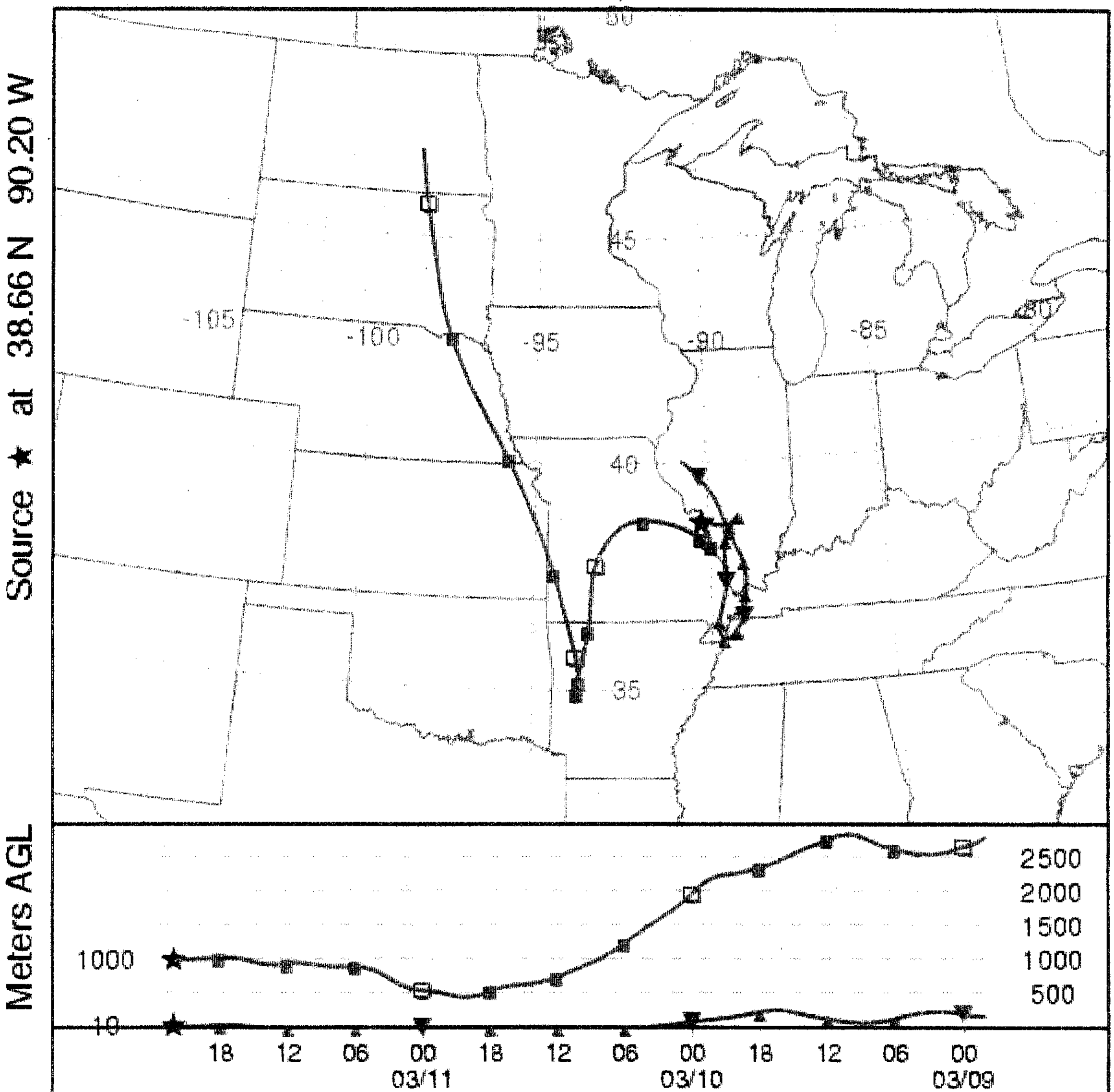
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 08 Mar 01
EDAS Meteorological Data



Job ID: 338615 Job Start: Thu Sep 25 13:39:36 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

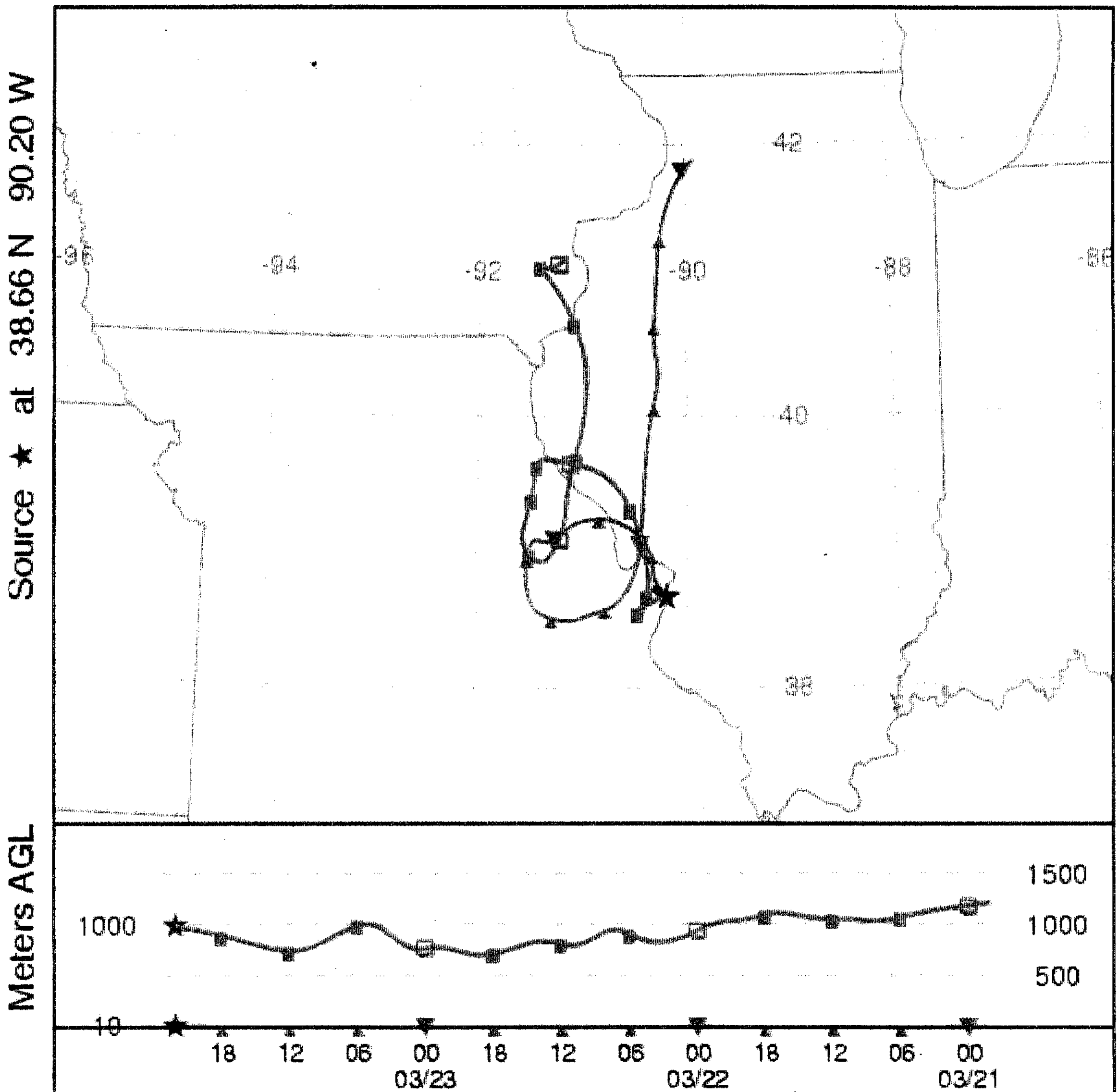
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 11 Mar 01
EDAS Meteorological Data



Job ID: 338622 Job Start: Thu Sep 25 13:40:52 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

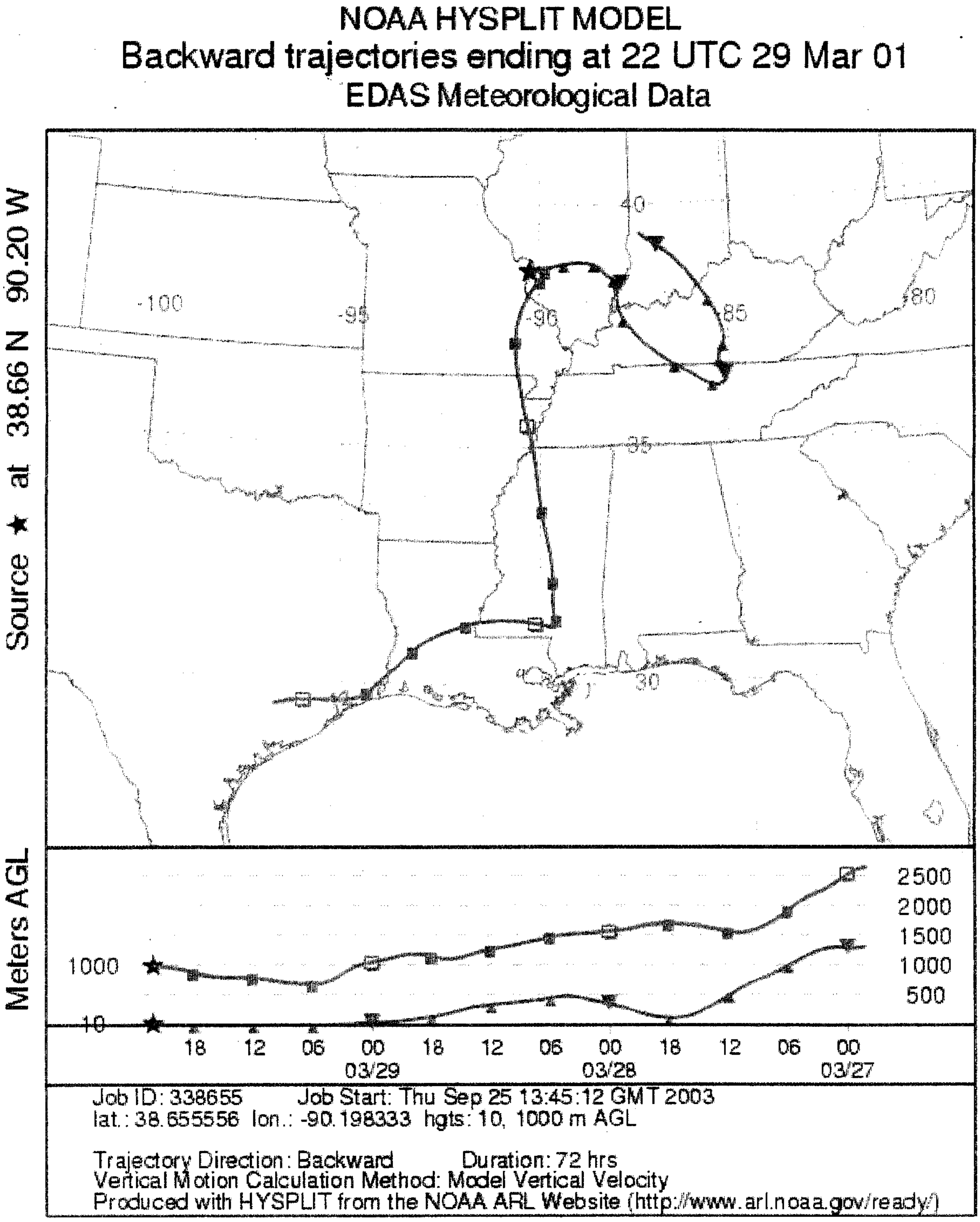
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 23 Mar 01
EDAS Meteorological Data



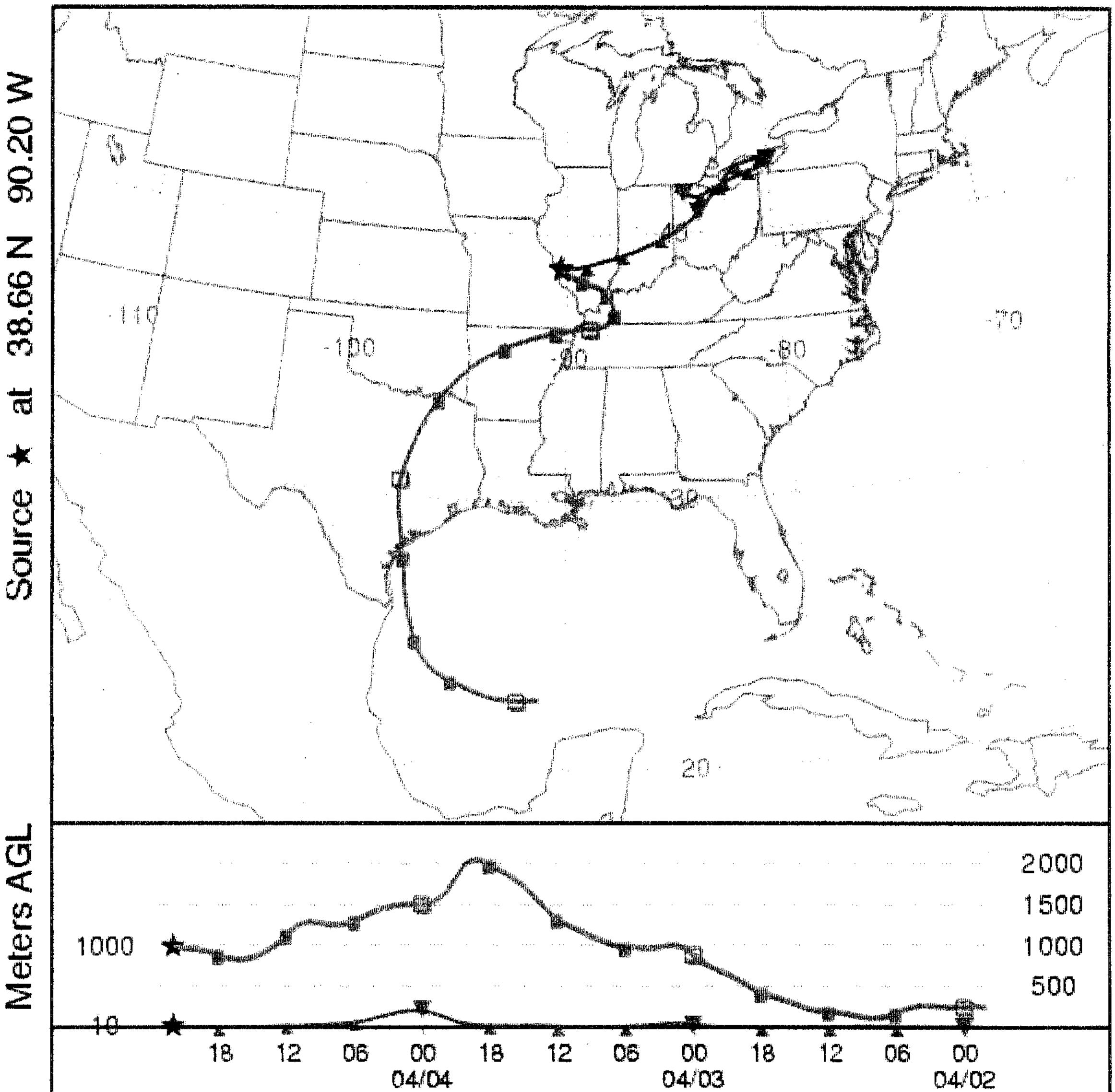
Job ID: 338642 Job Start: Thu Sep 25 13:43:16 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)



NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 29 Mar 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-100
-95
-90
-85
-80
40
35
30
Meters AGL
1000
10
2500
2000
1500
1000
500
18 12 06 00 18 12 06 00 18 12 06 00
03/29
03/28
03/27
Job ID: 338655 Job Start: Thu Sep 25 13:45:12 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

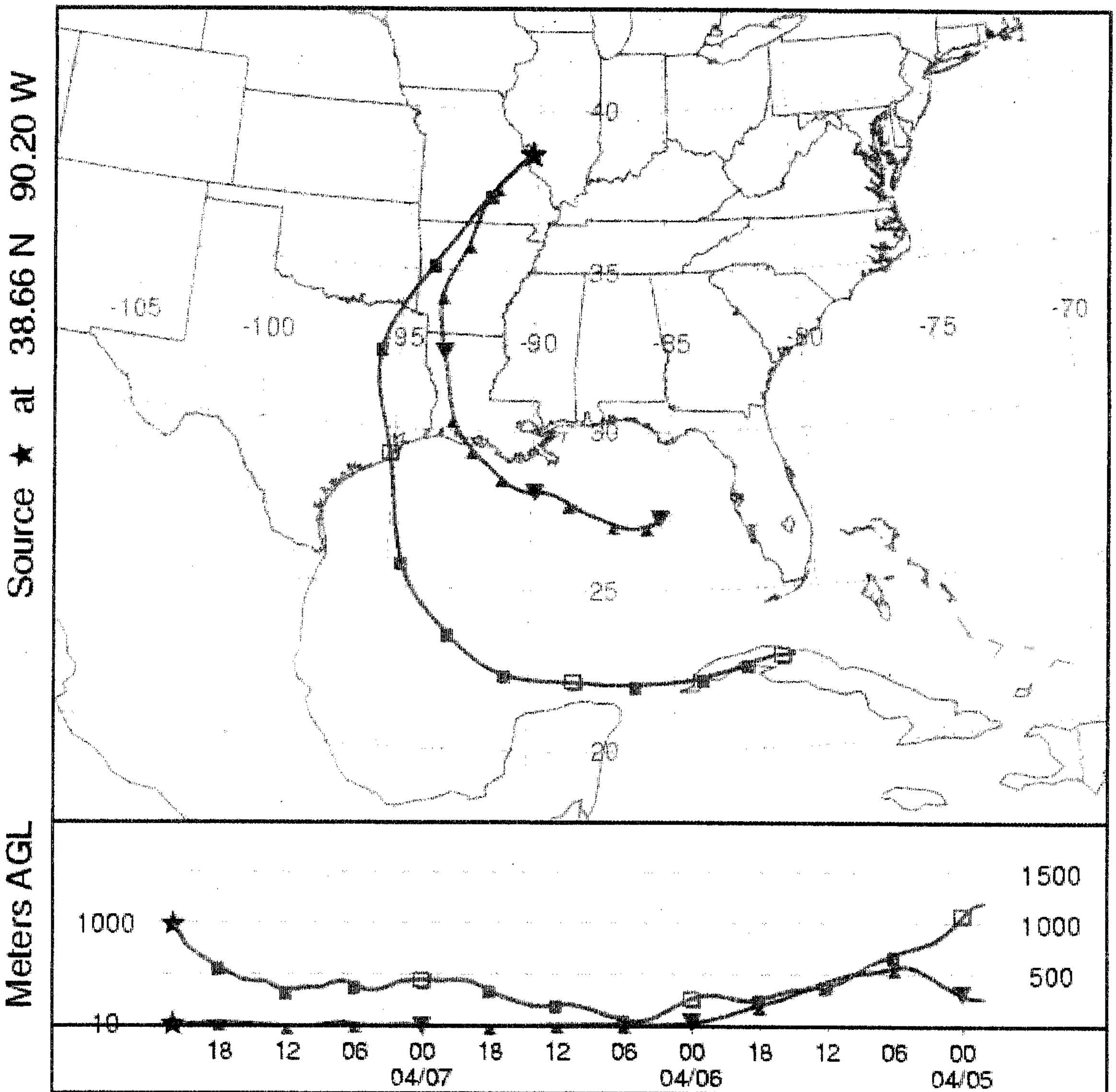
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 04 Apr 01
EDAS Meteorological Data



Job ID: 338661 Job Start: Thu Sep 25 13:47:49 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

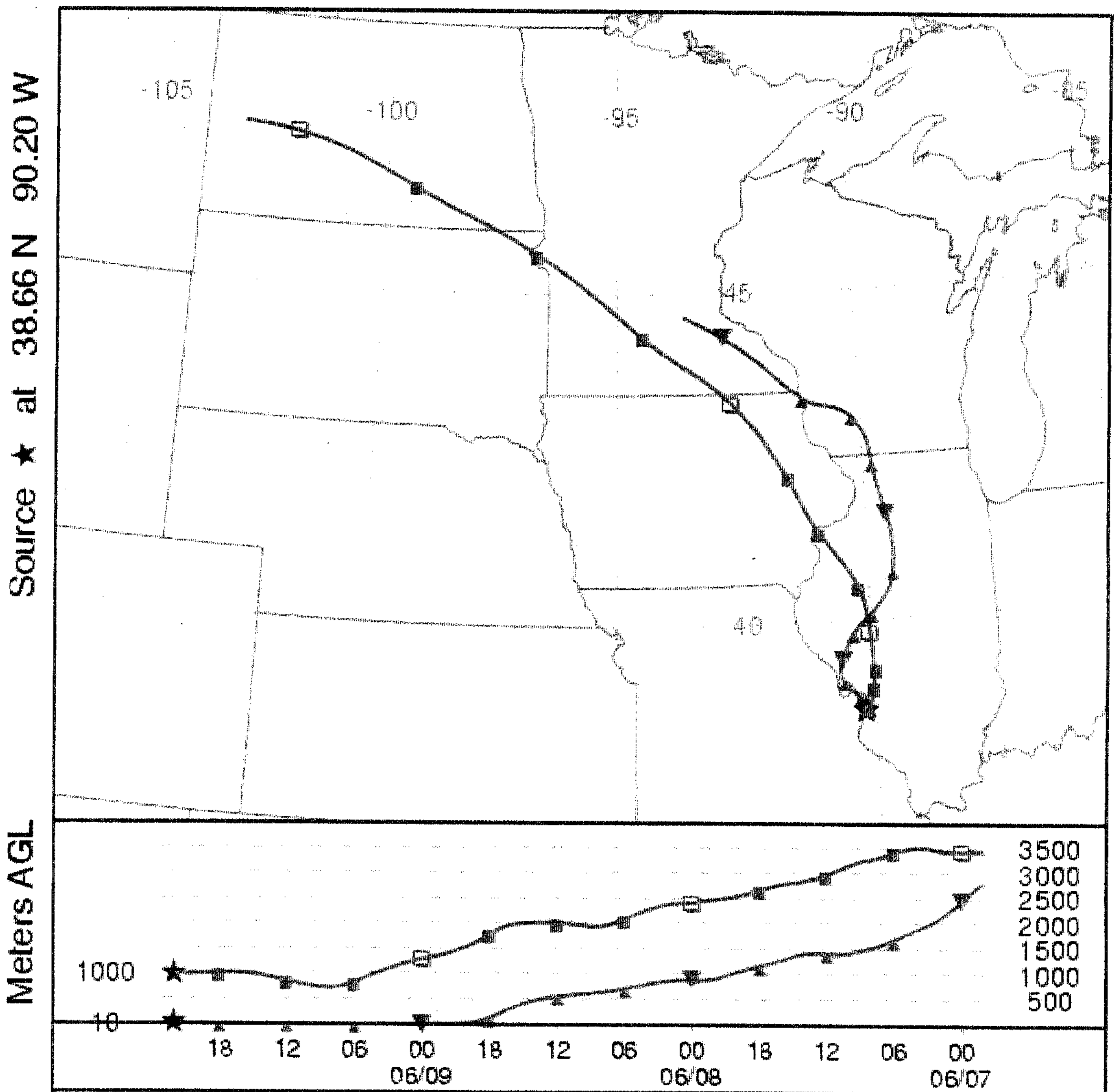
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 07 Apr 01
EDAS Meteorological Data



Job ID: 338678 Job Start: Thu Sep 25 13:49:23 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

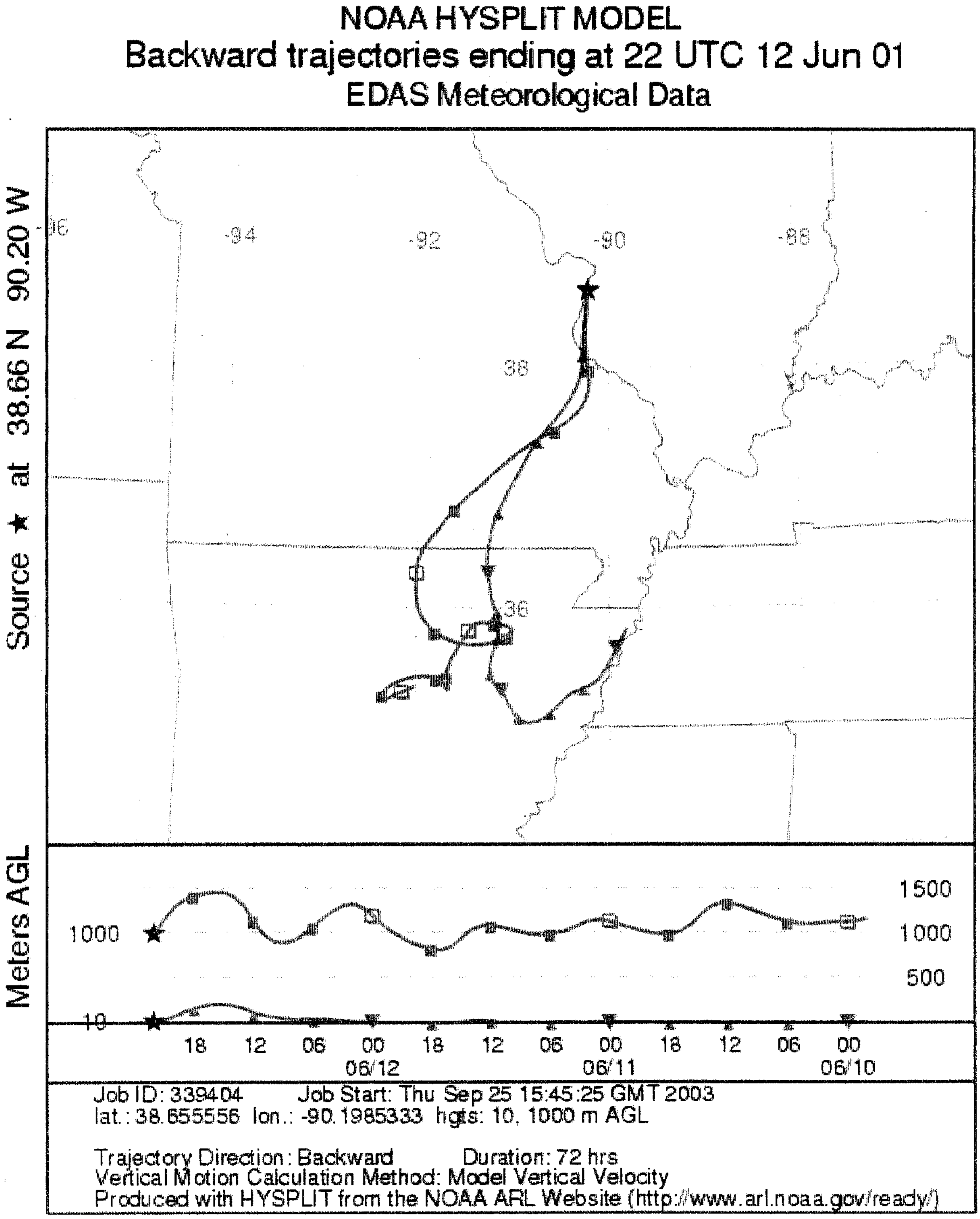
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 09 Jun 01
EDAS Meteorological Data

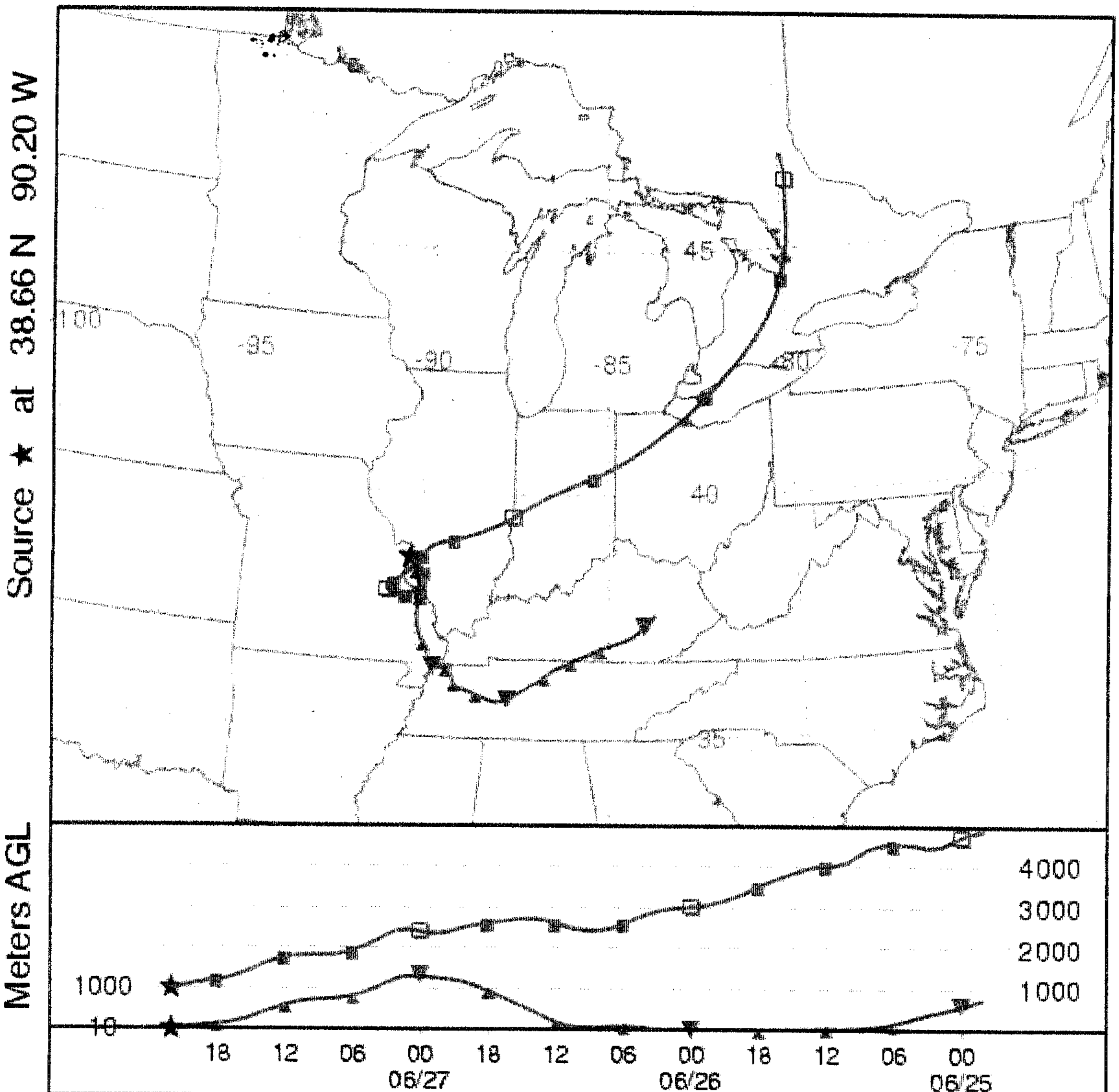


Job ID: 338734 Job Start: Thu Sep 25 14:16:32 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

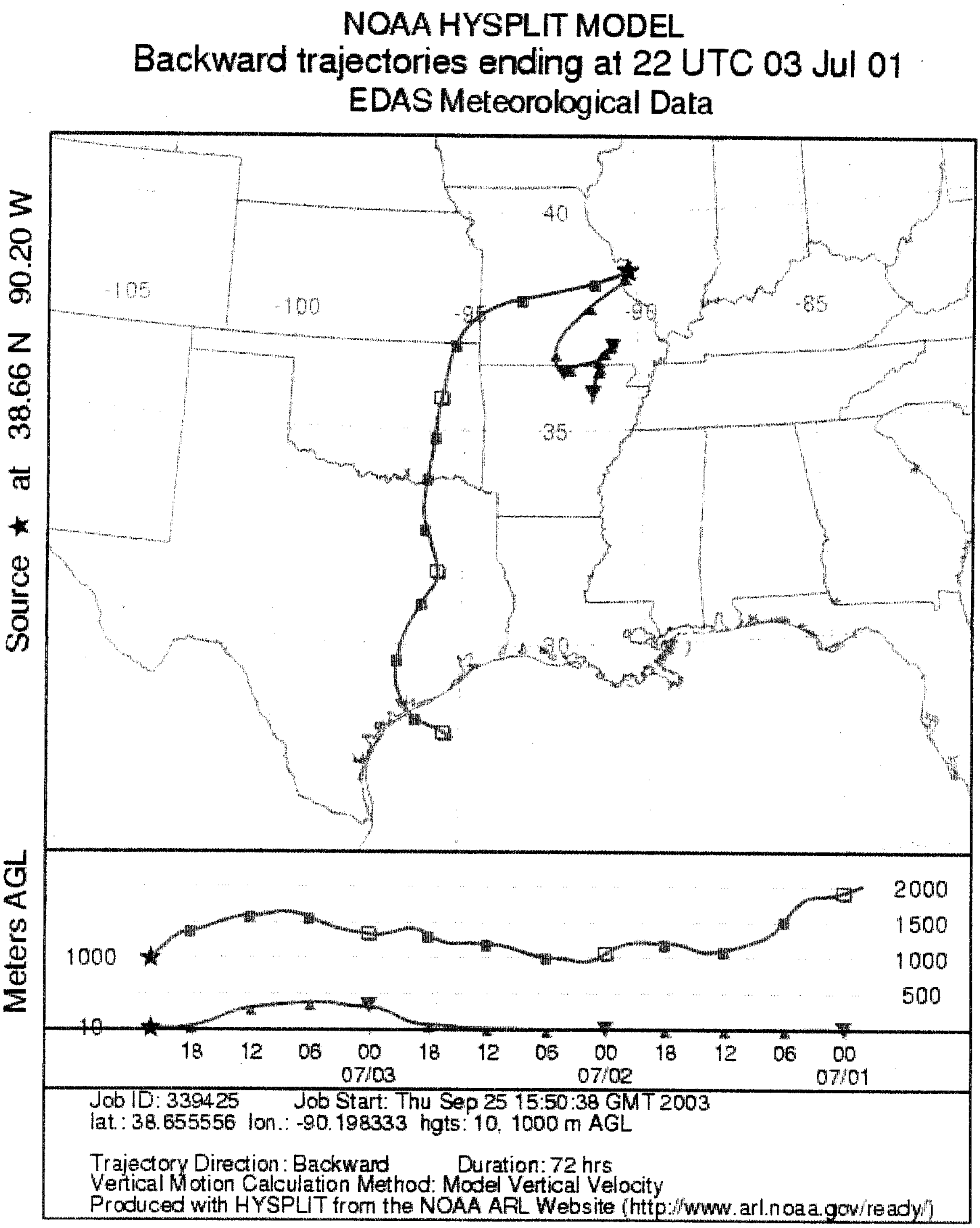

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 12 Jun 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-96
-94
-92
-90
-88
38
36
Meters AGL
1500
1000
1000
500
10
18 12 06 00 18 12 06 00 18 12 06 00
06/12
06/11
06/10
Job ID: 339404 Job Start: Thu Sep 25 15:45:25 GMT 2003
lat.: 38.655556 lon.: -90.1985333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 27 Jun 01
EDAS Meteorological Data

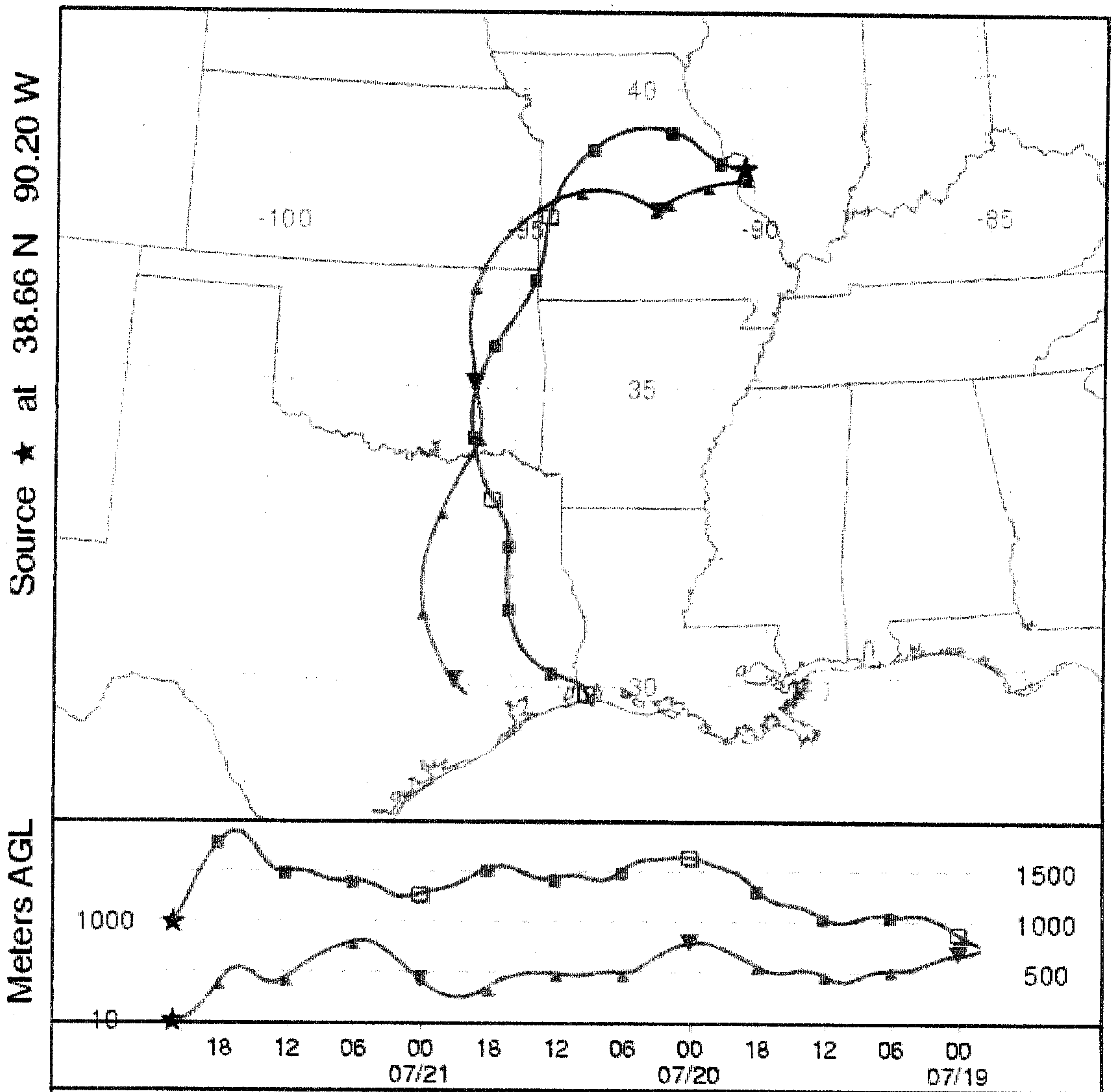


Job ID: 339416 Job Start: Thu Sep 25 15:47:55 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

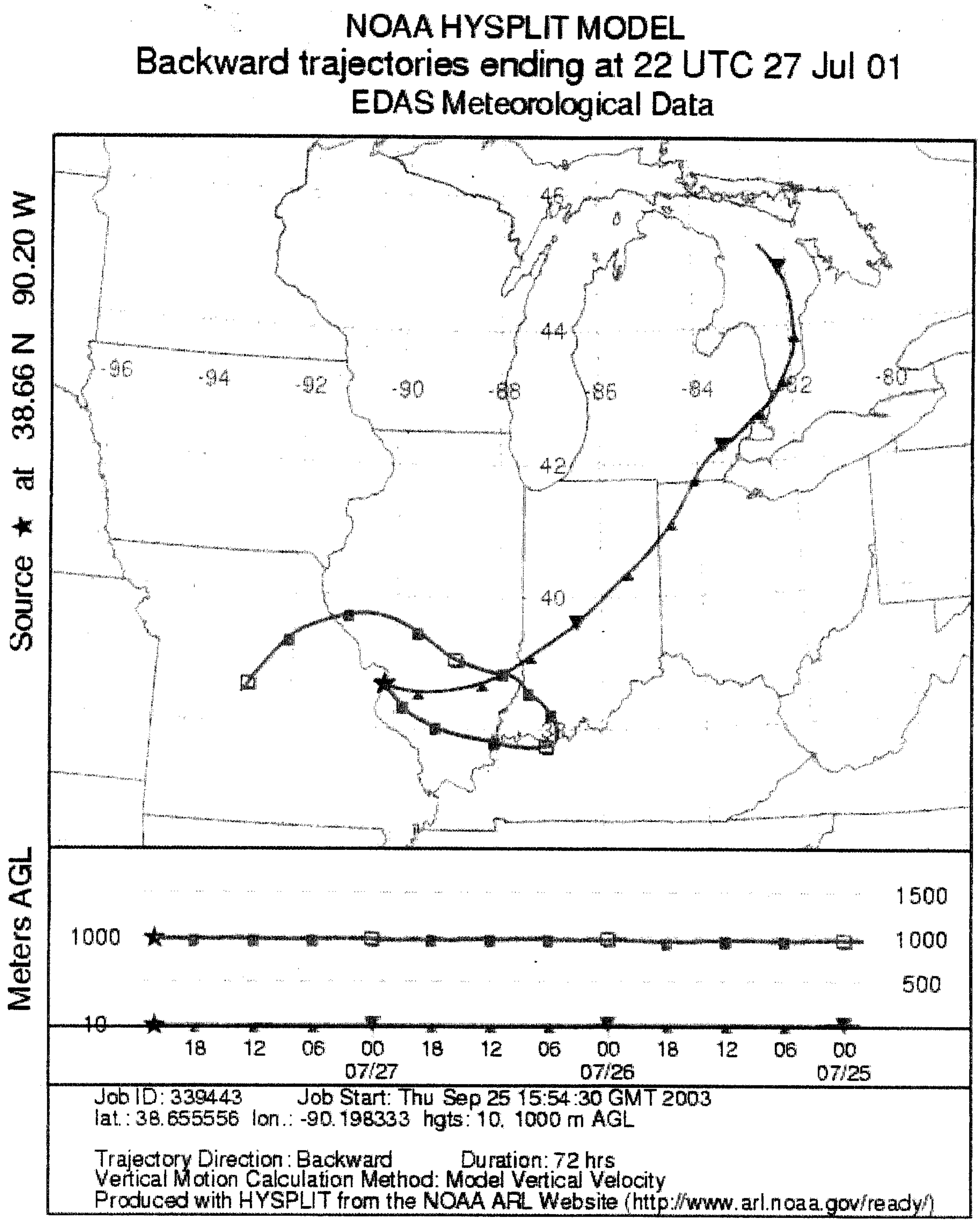

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 03 Jul 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
40
-105
-100
-95
-90
-85
35
30
Meters AGL
2000
1500
1000
500
1000
10
18
12
06
00
07/03
18
12
06
00
07/02
18
12
06
00
07/01
Job ID: 339425 Job Start: Thu Sep 25 15:50:38 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 21 Jul 01
EDAS Meteorological Data

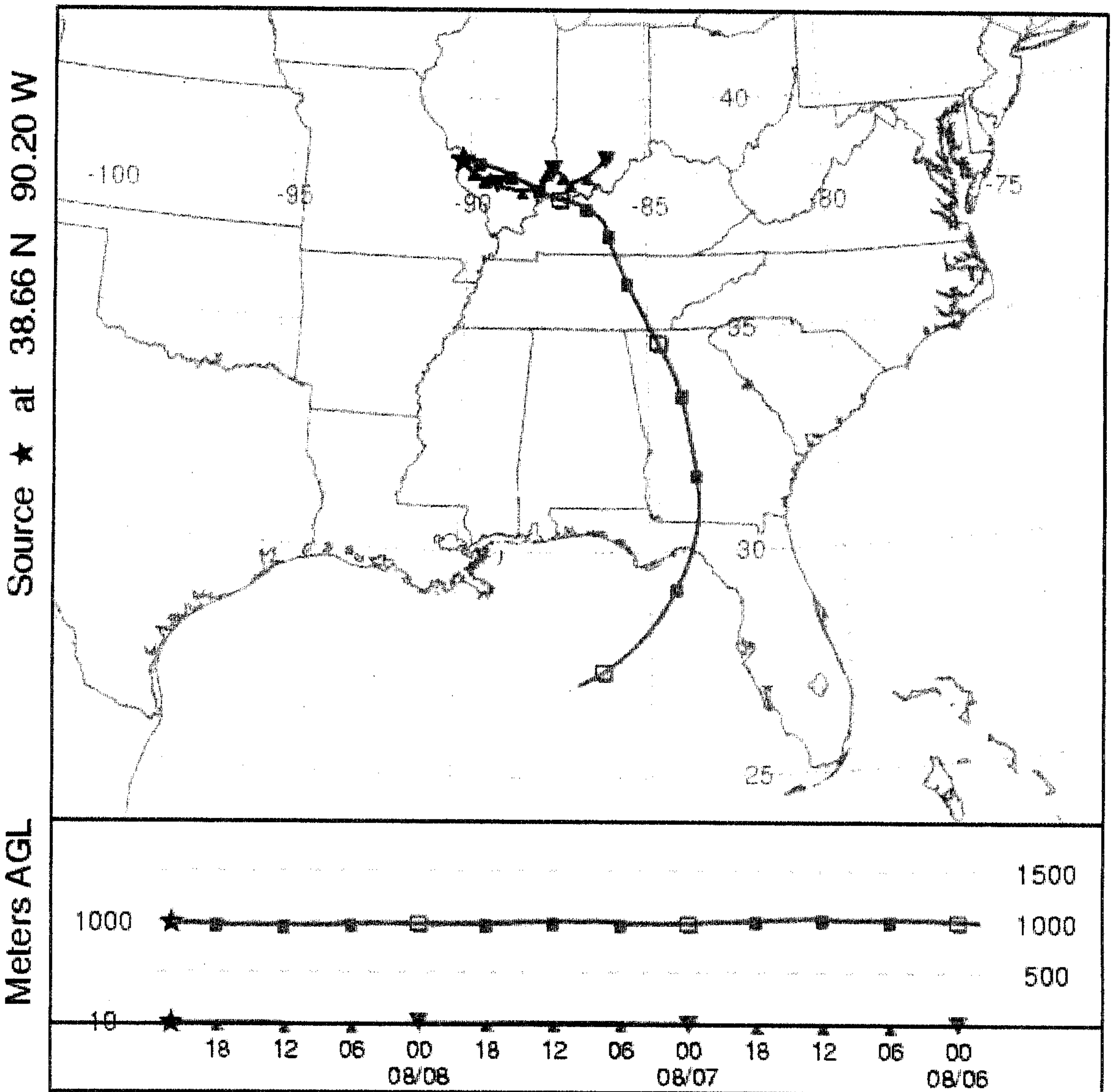


Job ID: 339434 Job Start: Thu Sep 25 15:52:54 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

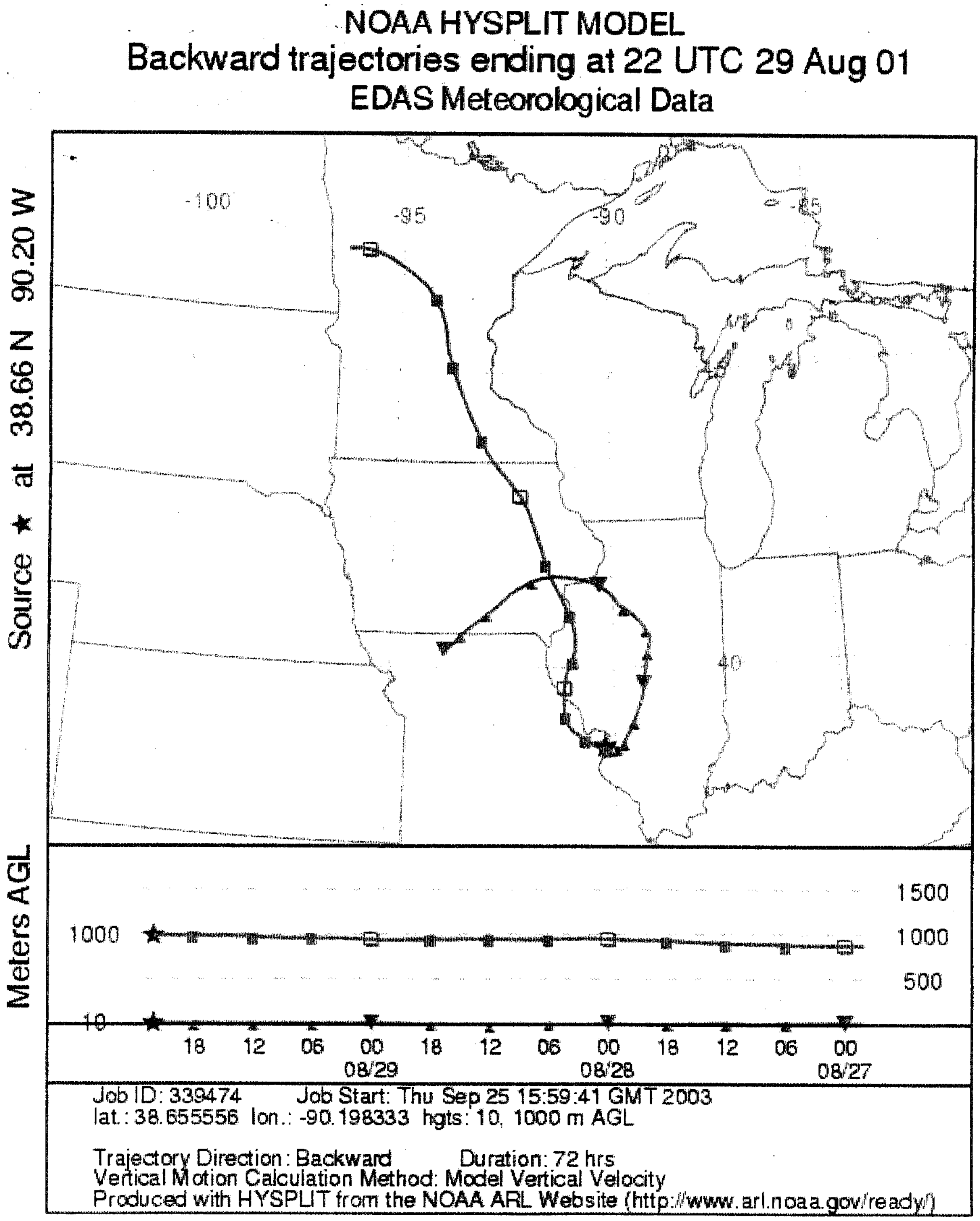

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 27 Jul 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
46
44
42
40
-96
-94
-92
-90
-88
-86
-84
-82
-80
Meters AGL
1500
1000
500
10
18 12 06 00 18 12 06 00 18 12 06 00
07/27
07/26
07/25
Job ID: 339443 Job Start: Thu Sep 25 15:54:30 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

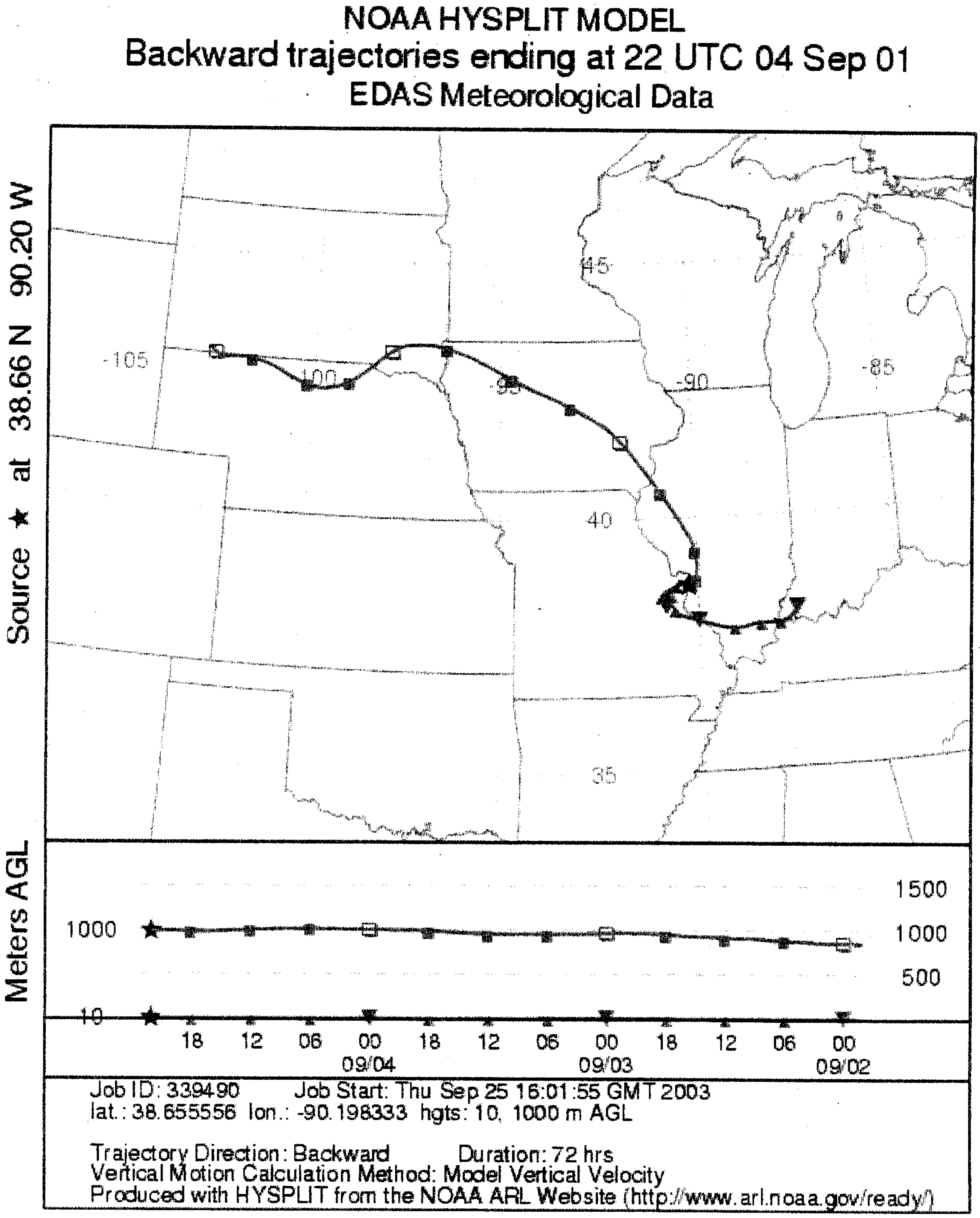
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 08 Aug 01
EDAS Meteorological Data

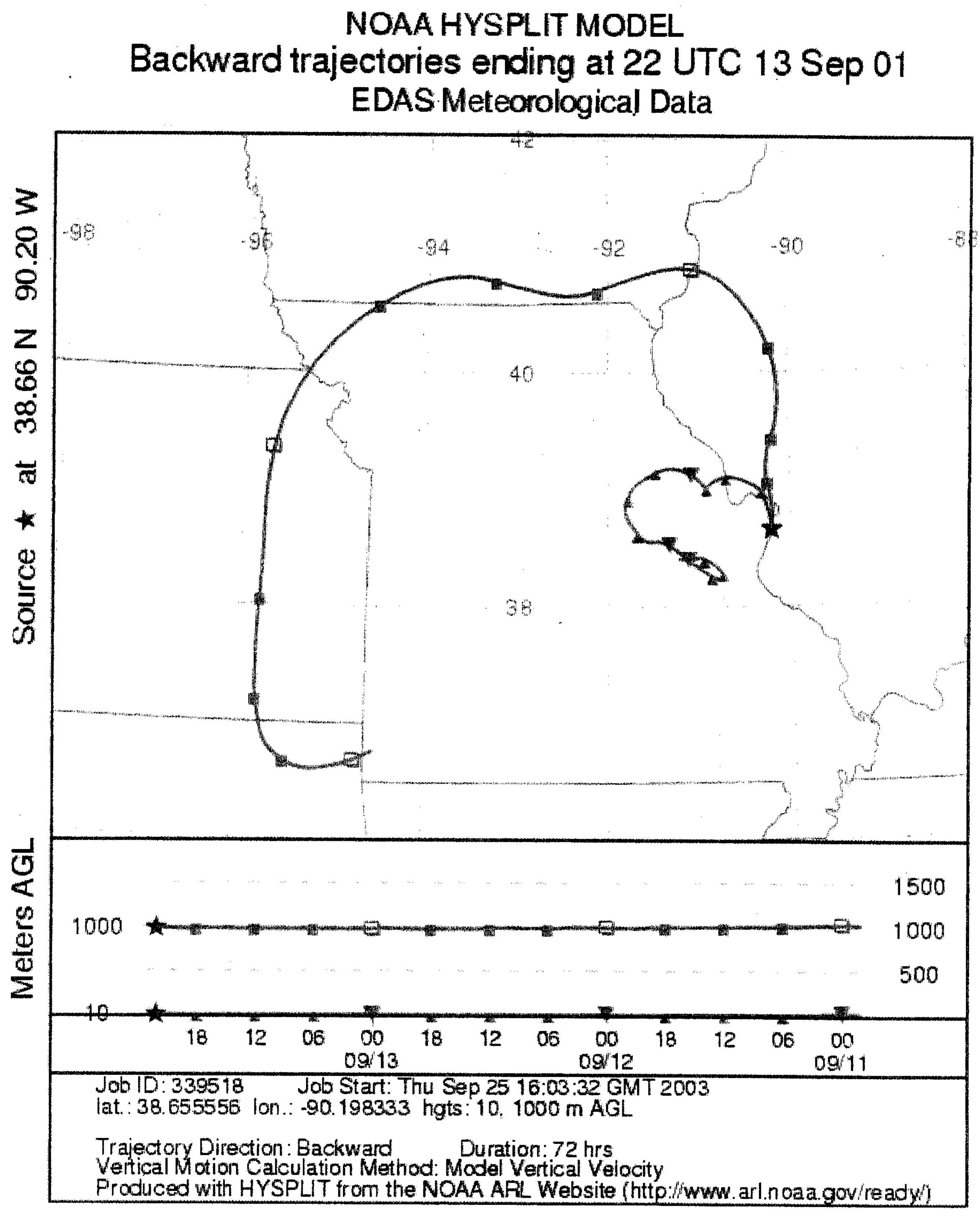


Job ID: 339455 Job Start: Thu Sep 25 15:57:11 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

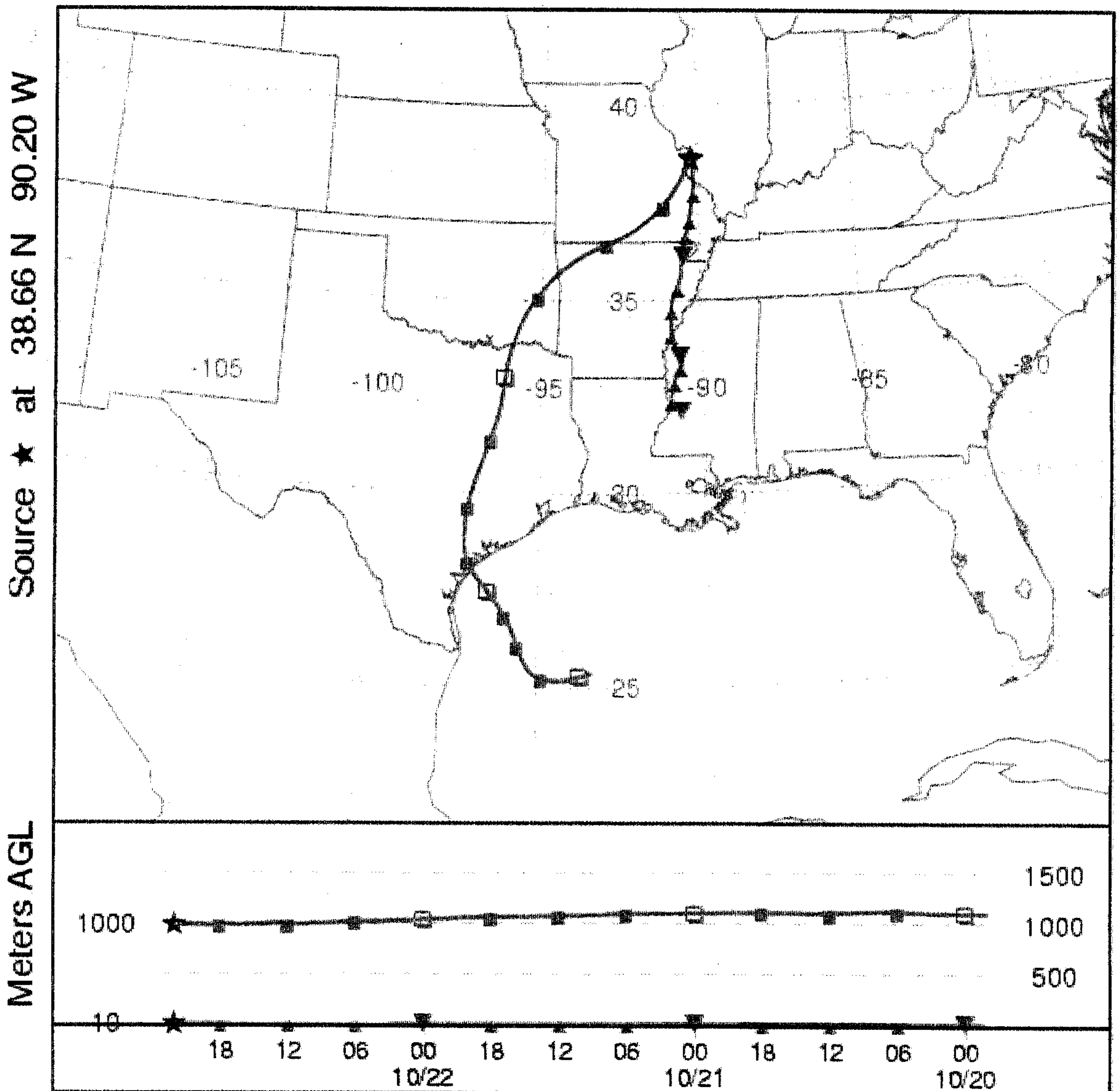
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 29 Aug 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-100
-95
-90
-85
40
Meters AGL
1500
1000
1000
500
10
18
12
06
00
08/29
18
12
06
00
08/28
18
12
06
00
08/27
Job ID: 339474 Job Start: Thu Sep 25 15:59:41 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 04 Sep 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-105
-100
-95
-90
-85
45
40
35
Meters AGL
1500
1000
500
10
18 12 06 00 18 12 06 00 18 12 06 00
09/04
09/03
09/02
Job ID: 339490 Job Start: Thu Sep 25 16:01:55 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

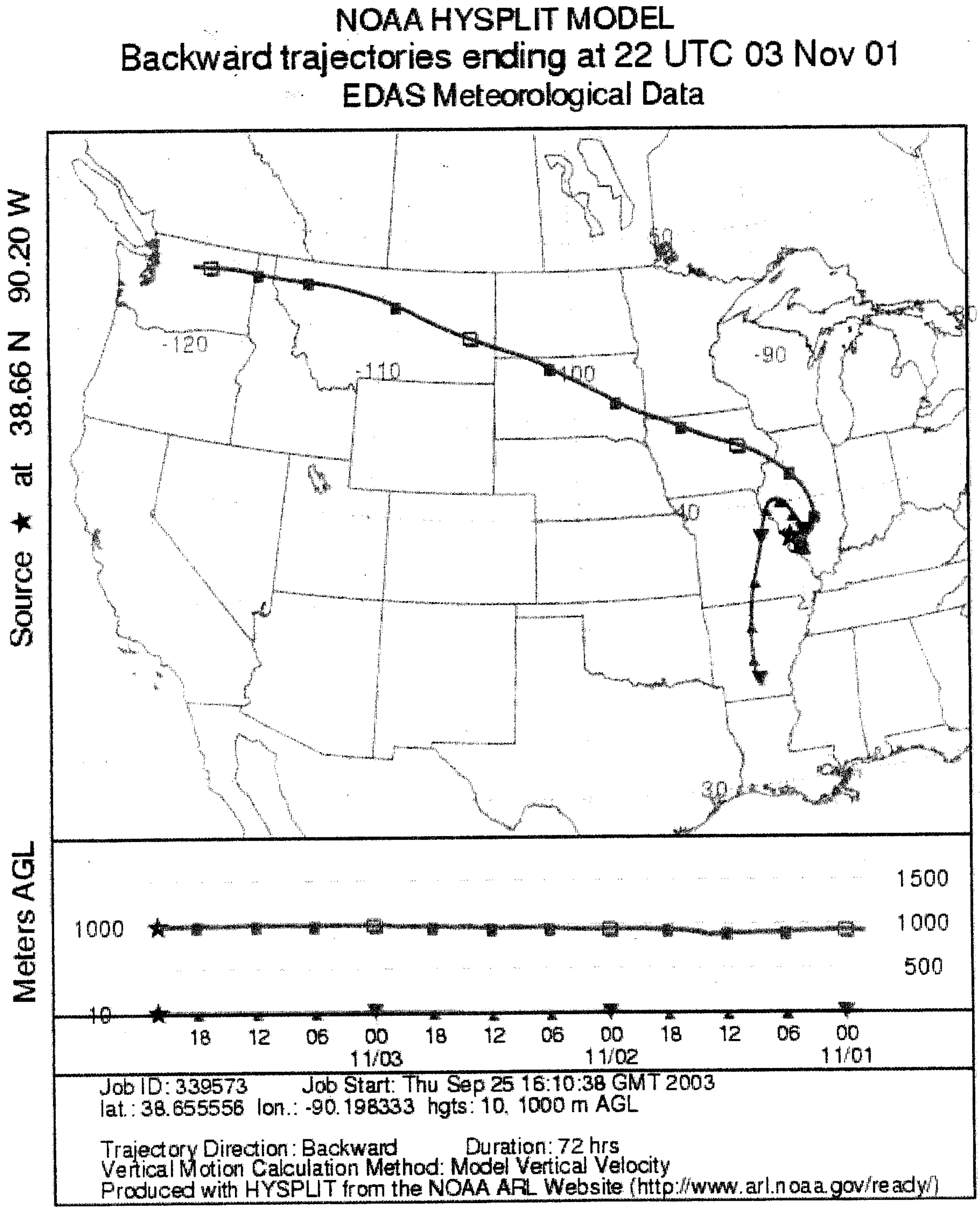

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 13 Sep 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-98
-96
-94
-92
-90
42
40
38
Meters AGL
1500
1000
500
1000
10
18 12 06 00 18 12 06 00 18 12 06 00
09/13
09/12
09/11
Job ID: 339518 Job Start: Thu Sep 25 16:03:32 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

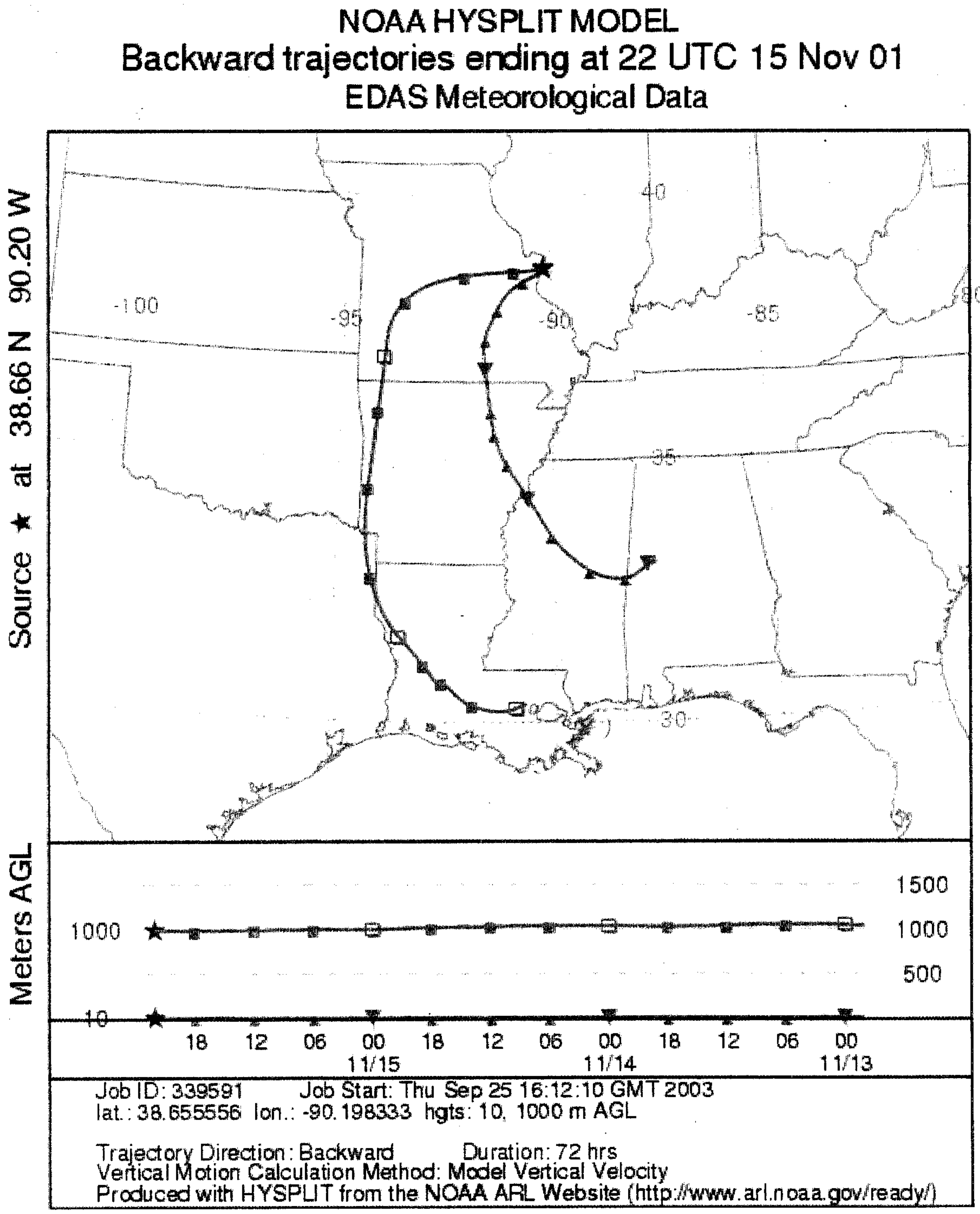
NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 22 Oct 01
EDAS Meteorological Data



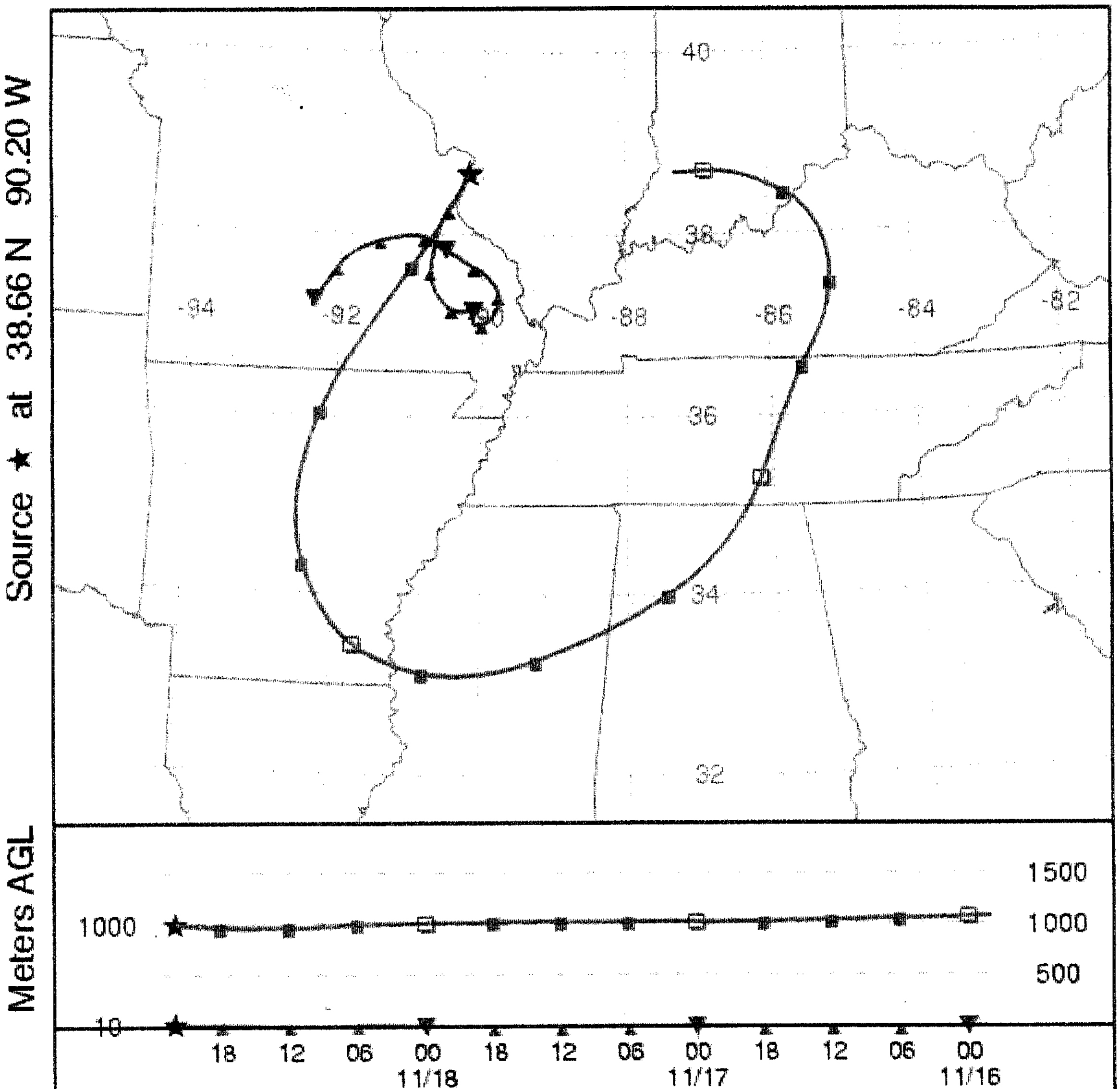
Job ID: 339561 Job Start: Thu Sep 25 16:08:01 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 03 Nov 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-120
-110
-100
-90
40
30
Meters AGL
1500
1000
500
1000
10
18 12 06 00 18 12 06 00 18 12 06 00
11/03
11/02
11/01
Job ID: 339573 Job Start: Thu Sep 25 16:10:38 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)


NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 15 Nov 01
EDAS Meteorological Data
Source ★ at 38.66 N 90.20 W
-100
-95
-90
-85
-80
40
35
30
Meters AGL
1500
1000
500
10
18 12 06 00 18 12 06 00 18 12 06 00
11/15
11/14
11/13
Job ID: 339591 Job Start: Thu Sep 25 16:12:10 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL
Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 22 UTC 18 Nov 01
EDAS Meteorological Data



Job ID: 339629 Job Start: Thu Sep 25 16:14:52 GMT 2003
lat.: 38.655556 lon.: -90.198333 hgts: 10, 1000 m AGL

Trajectory Direction: Backward Duration: 72 hrs
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)